Aeronautical Engineering REVIEW

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Cover—The Ultra-Light jet, said to be one of the world's smallest helicopters, has been introduced by Piasecki Aircraft Corp., representing the designer and manufacturer, Fairey Aviation Co., Ltd., Great Britain. Piasecki Model 72 will be the American version of the aircraft which is driven by a propulsive system of pressure jets at the rotor blade tips. Piasecki reports this means of propulsion and simple design eliminates gears, clutches, shafts, and the antitorque rotor on the tail. Rotor diameter is 28 ft., 3.5 in., empty weight 995 lbs., top speed 105 m.p.h. (Turbomeca "Palouste" turbine engine), and normal gross weight 2,200 lbs.

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NEW CONTINUOUS HIGHLY SELECTIVE,

Light, Simple System Overcomes False Alarming

ASHLAND, MASS. — Tubes, transistors, relays, and moving parts will give no trouble in Fenwal's new Continuous Over-Heat and Fire Detector, because the Detector uses none of these. The bugs are not only out of it — they never were in it.

This radical improvement in continuous detection is a small, flexible, seamless tube filled with an inorganic compound, with a nickel wire at its center, and a control unit that receives and amplifies electrical changes anywhere in the tube. Excessive heat anywhere along the tube lowers the resistance of the tube, and promptly triggers an alarm.

The Detector can be called a radical improvement for a number of reasons, but the basic reason is this: *the salt filler used by Fenwal gives such startlingly sharp drops in resistance with rising temperatures that the length of the loop hardly matters.* The temperature responses of a one-foot length and a twenty-foot length of the Detector tube are actually within 10° F of each other!

In short — the bugbear of almost all previous continuous fire detectors, so-called *averaging*, has been licked. With that bugbear licked, look at all the things Fenwal's new system can mean to aircraft safety!

CONTROL UNIT — Contains no components subject to wear or breakdown. Not bothered by shock and vibration. Not position sensitive. Hermetically-sealed. Weighs only 9 ozs.

No longer do alarm systems have to be set to trigger at dangerously high temperatures in order to minimize false alarming. Set to give the alarm at realistically low temperatures, the Fenwal system will not false alarm, and will give a true alarm instantly — giving precious seconds for remedial action.

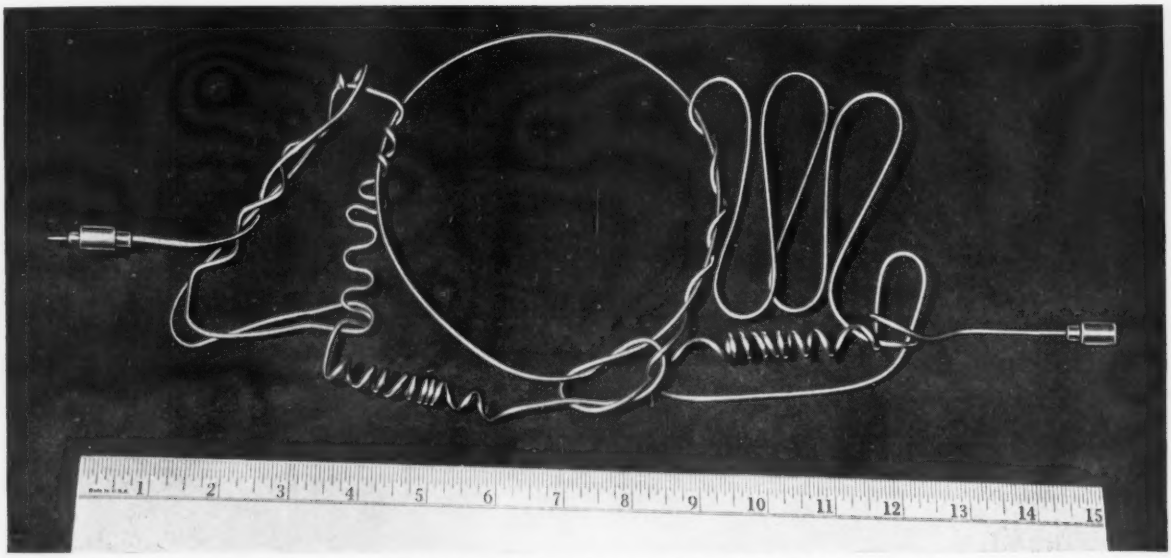
Wide-spread fire or over-heat conditions and localized hot spots trigger alarms at virtually identical temperatures.

Aircraft can now have continuous fire and over-heat detection that is, in effect, a network of unit detectors, monitoring a widely varying series of temperature situations. Lengths of sensing tube, each set to trigger the alarm at a different temperature, can be joined in a single loop, without one segment's affecting the performance of any other segment.

Fenwal has developed and tested exhaustively a large family of detectors for service over a range from 350° F to 2000° F.

The reliability and durability is due, in large measure, to the novel design of the control unit. The unit,

FIRE DETECTOR RELIABLE, ACCURATE



SELECTIVE, ACCURATE DETECTOR — So flexible it can be bent into any shape. Extremely low impedance virtually eliminates continuous-fire-detection bugbear of false alarming.

small enough to fit in the palm of a hand, is a hermetically-sealed magnetic amplifier which, when the alarm temperature is reached, amplifies the changes occurring in the detector loop and actuates alarms. It is light, tough, and not in the least position sensitive.

Write for full details to **Fenwal Incorporated, Aviation Products Division, 177 Pleasant Street, Ashland, Massachusetts.**

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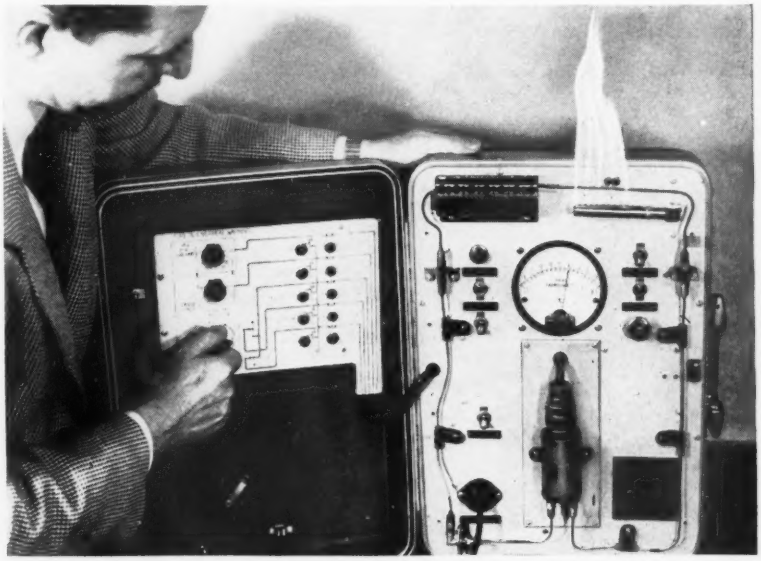
. . . *Precisely*



EXHAUSTIVE TESTS—Mock-up of detection loop (mounted on right panel) is tested with flame, demonstrates conclusively that it triggers alarm at same temperature despite variable ambient temperatures along loop and regardless of the length of loop exposed.

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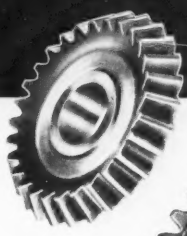

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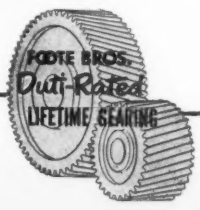

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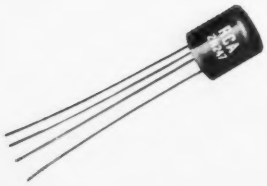
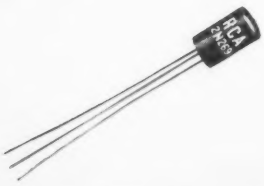
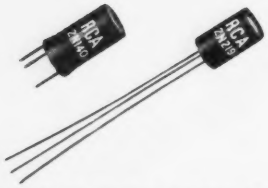


RCA-2N247—"Drift" Transistor for use as an RF amplifier in the AM broadcast-band and up into the short-wave bands. Flexible leads.

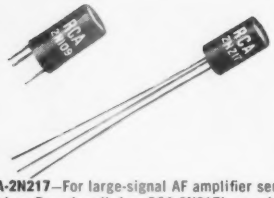


RCA-2N269—For low-level, medium speed, on-off, control applications as in flip-flop and gating circuits of electronic computers. Flexible leads.

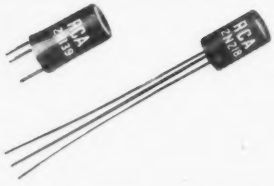
RCA-2N206—For moderate-power AF amplifier service. Meets military specification MIL-T-25380/4 USAF. (Max. collector dissipation, 75 mw. at ambient temp. of 25°C.) Flexible leads.



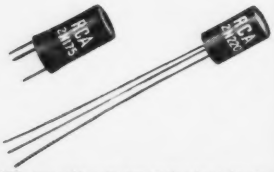
RCA-2N219—For converter and mixer-oscillator applications in standard-AM broadcast-band receivers. Has flexible leads. For linotetrar 3-pin base version, specify **RCA-2N140.**



RCA-2N217—For large-signal AF amplifier service. In class B push-pull, two RCA-2N217's can deliver max. signal power output of approximately 150 milliwatts. Has flexible leads. For linotetrar 3-pin base, specify **RCA-2N109.**



RCA-2N218—For 455-Kc IF amplifier applications in standard-AM broadcast-band receivers. Has flexible leads. For linotetrar 3-pin base, specify **RCA-2N139.**



RCA-2N220—Exceptionally low-noise type for pre-amplifier or input stages of transistorized audio amplifiers operating from extremely small input signals. Has flexible leads. For linotetrar 3-pin base, specify **RCA-2N175.**

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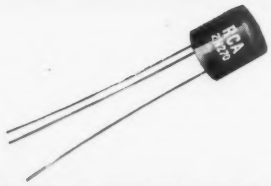

RCA-2N270—For large-signal AF amplifier service. In class A, one RCA-2N270 can deliver a max.-signal power output of approximately 60 milliwatts; in class B push-pull, a pair can deliver up to 500 milliwatts. Flexible leads.

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For technical data on RCA Transistors, write to RCA Commercial Engineering, Sec. H-87-NN, Somerville, N. J.

RCA SEMICONDUCTOR DIVISION
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Somerville, N. J.

BILL FOX, Convair's Senior Project Engineer on the F-102A, was graduated from the University of Virginia (BSME) in 1943. He has been with CONVAIR-SAN DIEGO since graduation, except for nine months with the U.S. Air Force. His success at Convair underscores the career opportunities for engineers at this "young man's company."

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"A prototype of the F-102, Convair's unique delta-wing interceptor, was being tested. While design changes were being evaluated, our aerodynamics group at CONVAIR-*SAN DIEGO* recommended the application of a new N.A.C.A. theory – 'Area Rule' – that would reduce the airplane's drag in the transonic range . . . push its speed beyond Mach 1.

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"Important as this project was, it represents only *one* of the many creative assignments being solved at CONVAIR-*SAN DIEGO*—on projects like our F-102A Interceptor and Convair's 880—world's fastest Jetliner.

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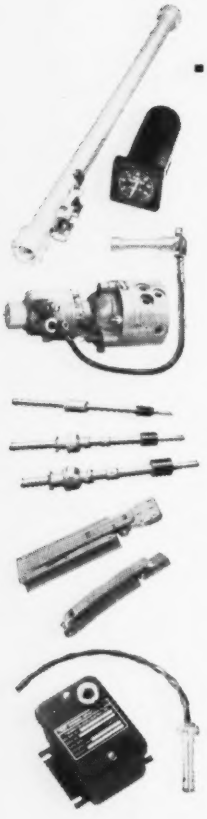

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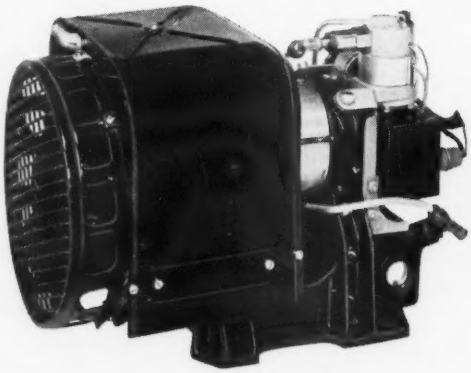
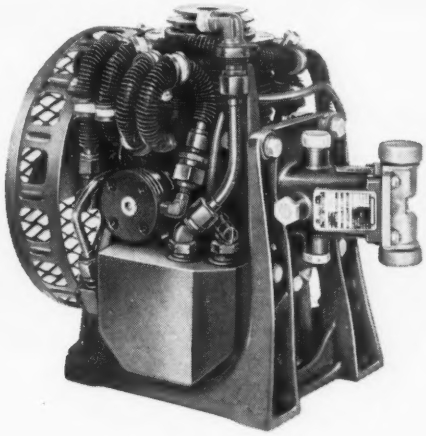
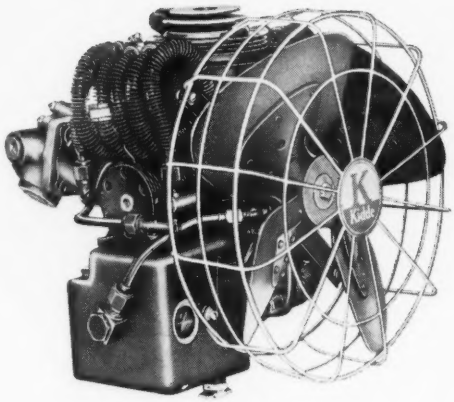


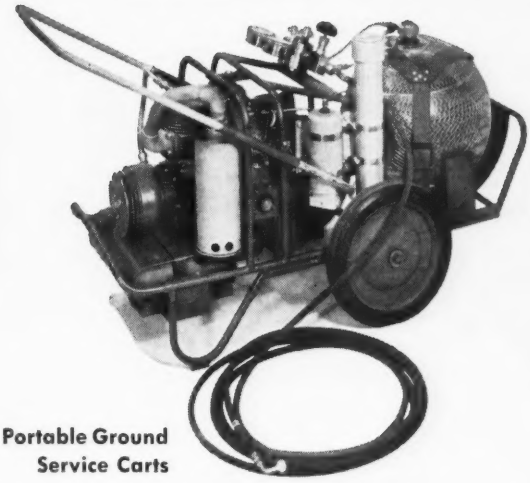
2 cfm Compressor Package



4 cfm Compressor



6 and 8 cfm Compressors



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Also in production is the compact, portable 4 cfm ground service cart (above, lower right) which supplies dry air (stored in shatterproof, wirewound steel sphere) from 50 to 3,000 psi. Kidde has ground service carts and compressors with higher outlet pressures, larger capacities and various type drives which can be made to meet your exact specifications. For full information, write to Kidde today.

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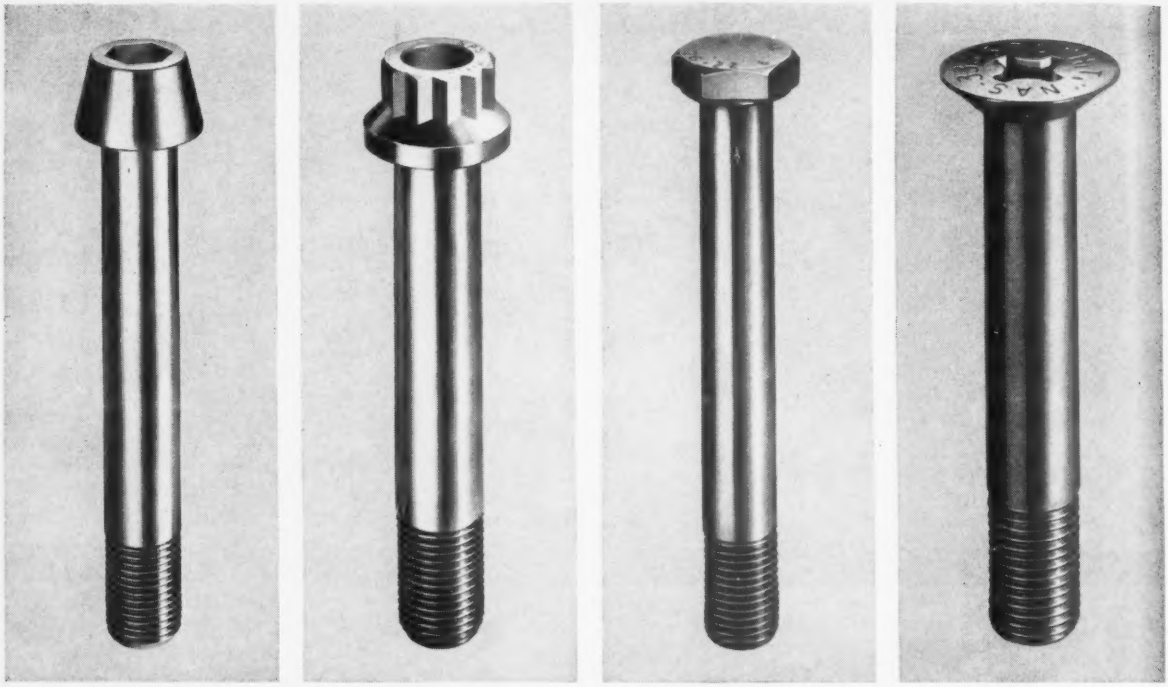
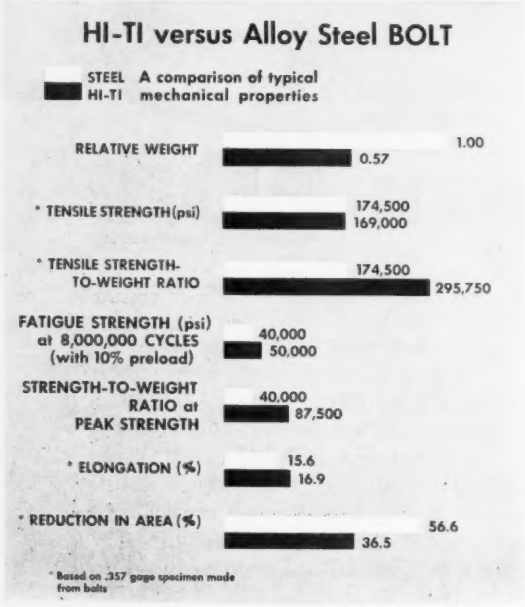


SPS Hi-Ti titanium aircraft bolts are regularly manufactured in four standard configurations: internal wrenching tension bolts, 12-point external wrenching tension bolts, hexagon head external wrenching shear bolts, and flush head internal wrenching shear bolts. Weighing 43% less than steel bolts of equivalent dimensions, they can save you as much as 1000 lb. per airframe—with no loss in strength.

SPS Hi-Ti titanium bolts help you build lighter airframes without sacrificing strength



Hi-Ti vs. alloy steel. Tensile, elongation and reduction area properties are based on the performance of bolt gage specimens. Endurance limit was determined by subjecting bolts to tension load alternating between maximum and 10% preload for a total of 8,000,000 cycles without inducing failure. Significant comparison is the strength-to-weight ratio at endurance limit.

SPS Hi-Ti titanium bolts help you solve the problem of reducing airframe weight without compromising strength. They weigh 43% less than alloy steel bolts of the same size. One lb. of them can do the work of 1¾ lb. of steel bolts. Yet in tensile-strength-to-weight ratio and fatigue resistance, they outperform steel.

Once considered a laboratory curiosity, titanium bolts have for some time been standard production items at SPS. Hi-Ti bolts are found in many advanced design operational aircraft. This is because SPS—producer of the first successful titanium aircraft bolt—invested over $500,000 and several years of high priority research in learning how to deal with this promising but sensitive metal. Today SPS has the most extensive facilities in the industry for the production and testing of titanium fasteners. As a result, we can give you both the technical assistance and the delivery you need to utilize fully the advantages of titanium bolts in your current airframe projects.

For more information on Hi-Ti titanium aircraft bolts, write Aircraft Products Division, STANDARD PRESSED STEEL Co., Jenkintown 58, Pa.

AIRCRAFT PRODUCTS DIVISION

STANDARD PRESSED STEEL CO.
SPS
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AIRCRAFT and MISSILE SYSTEMS and COMPONENTS

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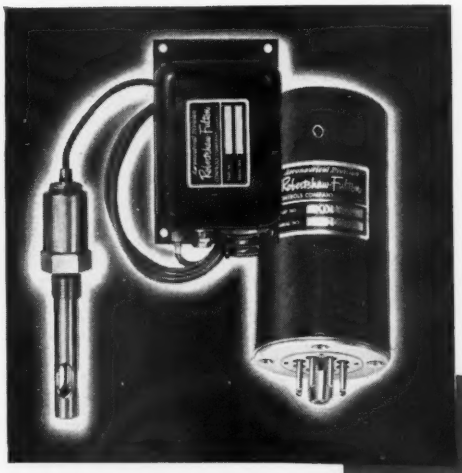


where liquid level is critical

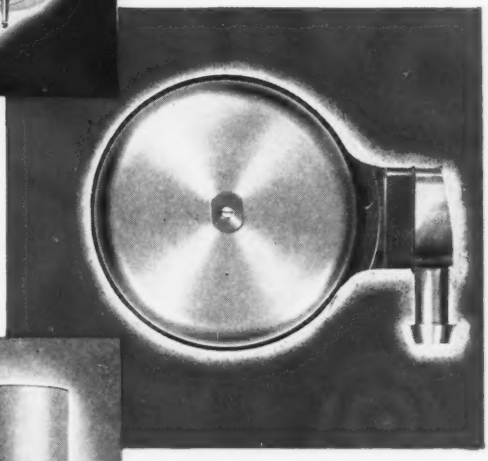
LIQUID LEVEL SWITCH

A new degree of accuracy and reliability is provided by this new Liquid Level Switch. The unit utilizes the absorptive properties of liquids to radioactive emission, achieving precise liquid level indication.

where frequency must remain constant

CRYSTAL OVEN

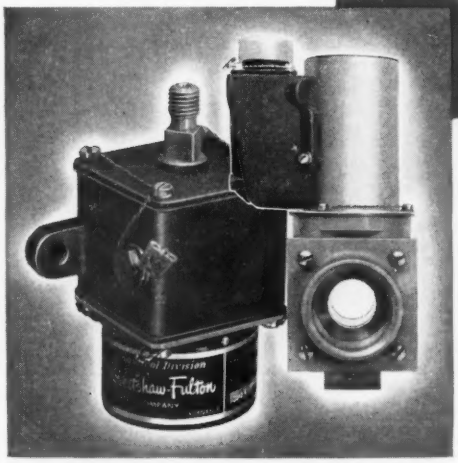
By employing the melting point characteristics of crystalline substances, this new compact Crystal Oven maintains extremely stable crystal cavity temperatures. Temperature tolerance is ±0.1°C.



where altitude builds fatigue

MINIATURE OXYGEN REGULATOR

Helmet or mask mounted, this new ultra-compact regulator allows effortless breathing . . . eliminates many of the bulky fittings previously required. The regulator is available as either a straight demand or demand with automatic pressure breathing unit.



where friction is kept to a minimum

BALL VALVE

This new Ball Valve overcomes frictional limitations characteristic of conventional designs through the use of a unique pressure balance seal.

where damping is a vital factor

VISCOUS DAMPER

This device makes use of the viscous properties of silicone fluid to effect controlled damping of rotary shafts. Damping range is 2.25 to 56.5 in-lb/radian/sec at 70° ± 5°F. Damper operates to −107°F.

For complete information on these products write for technical bulletins.

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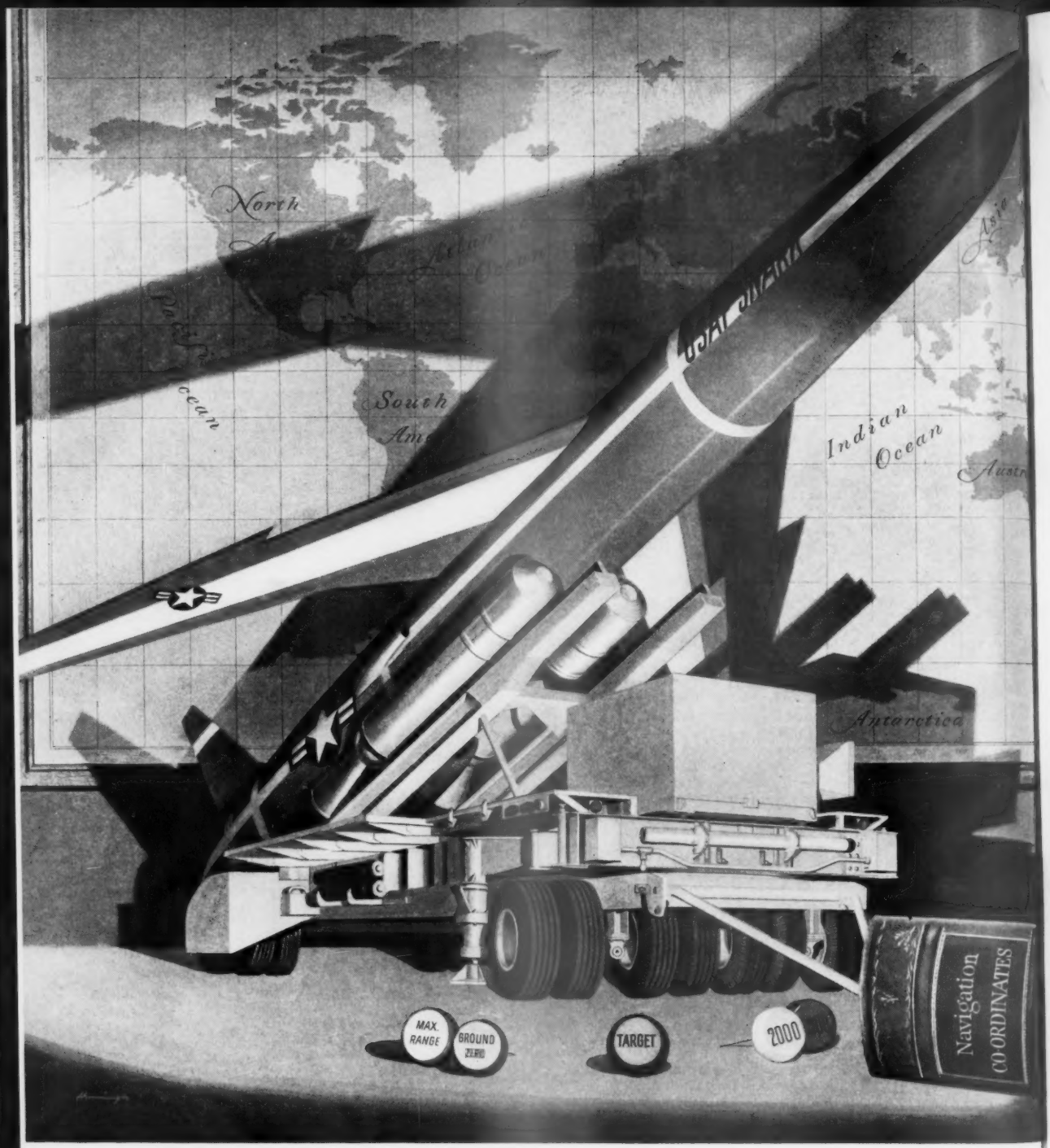

GLOBAL GUARDIAN—Nowhere can an aggressor take refuge from America's mighty instrument of retaliation, the Northrop Snark SM-62... world's first intercontinental guided missile, now scheduled for delivery to the Strategic Air Command of the U.S. Air Force. These pilotless bombers are designed to carry nuclear warheads with unerring accuracy over intercontinental ranges. Snark missiles can be launched in mass from sites thousands of miles from their targets. This forceful deterrent to attack is an existing product of Northrop's "years ahead" engineering. Missiles, drones, supersonic jet aircraft, ground support and armament equipment, integrated weapon systems and other vital national defense elements are being developed and produced at Northrop, where simplicity and economy are vital elements in the continuing search for weapon systems to guard tomorrow's free America.

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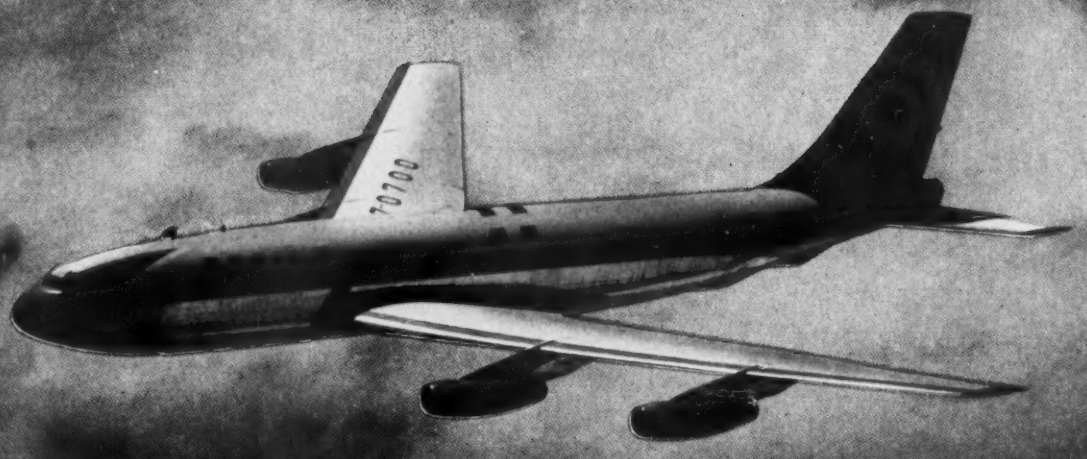
Builders of the First Intercontinental Guided Missile

BOEING 707
starts a new era of Jet Transportation



America's first jet airliner recently streaked across the country in three hours and 48 minutes for a new transcontinental passenger plane record. The plane carried 52 people and made the 2,325 miles from Seattle to Baltimore at an average speed of 612 miles an hour at altitudes of six miles and above.

To control such fast planes at high altitudes requires control cables designed to fit the application. Engineers at American Steel and Wire have cooperated with airplane manufacturers in designing American Tiger Brand Control Cables that meet the most rigid specifications. These cables have high strength, high resistance to bending fatigue, minimum stretch and the superior flexibility of Excellay Preformed Construction. They are used on all types of planes from fighters to heavy bombers. Write for complete information or call our nearest sales representative.

The Boeing 707 jet airliner ushers in a new era of fast transportation when it will be possible to have lunch in New York and dinner in San Francisco.

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United States Steel, General Offices: Cleveland, Ohio
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO • TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA., SOUTHERN DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS American Tiger Brand Aircraft Control Cables

UNITED STATES STEEL

Message from Melbourne

A recent short-wave broadcast from Melbourne, Australia . . . received in Syracuse, N. Y. (over 10,000 air miles) **with no perceptible flutter or fading** . . . is further proof that General Electric's new radio technique . . . Synchronous Amplitude Modulation*. . . is the solution to the problems of long-range radio operations. Its concept and operation are uniquely simple . . . SAM* is compatible with all present forms of radio equipment . . . its operators need no further specialized training . . . yet it preserves complex wave forms even while handling the Doppler effect. Its suppressed-carrier, double-sideband transmission and synchronous reception promise significant savings in weight and cost. Of paramount importance is SAM's* resistance to jamming and interference. Here again, is a vivid example of LMEE's invaluable contribution to progress... in furthering new uses for electronics.

For the very latest information on SAM* . . . write Section E

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IAS News Notes

August 1957

1932 Membership

Honorary Fellow	1
Scientific Members	
American	117
Foreign	62
Engineering Members	
American	219
Foreign	36
Pilot Members	
American	49
Foreign	1
Industrial Members	
American	118
Foreign	3
Total Membership	607

NEXT MONTH'S roster issue will commemorate the 25th anniversary of the Institute. The accompanying tables show a quarter century of growth.

1957 Membership

Honorary Members	16
Honorary Fellows	32
Fellows	213
Associate Fellows	1,138
Members	5,572
Associates	5,774
Student Members	4,397
Total Membership	17,142

THE CANADIAN AERONAUTICAL INSTITUTE-IAS Meeting will be held at Montreal's Sheraton-Mount Royal Hotel, October 21-22, and will feature technical sessions on space vehicles, engines, flight training, airline operations, navigation and traffic control, and education and training.

THE WATER-BASED AVIATION AWARD for 1957 will be presented to John B. Parkinson, Chief, Hydrodynamics Division, NACA Langley, for "sustained leadership in research on the hydrodynamics of water-based aircraft." The award will be made during the National Naval Aviation Meeting in San Diego, August 5-10.

THE WRITINGS OF THEODORE VON KÁRMÁN (HF), covering the years 1902-1951, have been published in four volumes titled "Collected Works of Theodore von Kármán" by Butterworths Scientific Publications, London, and Academic Press, Inc., New York.

THE AMERICAN HELICOPTER SOCIETY'S Fourth Annual Western Forum will be held October 20, 21 and 22, at the Statler Hotel, St. Louis, Missouri.

NEW SCRIP COUPONS, to eliminate sending checks, money orders or cash, may be used for payment for preprints of papers, dues, subscriptions, and other IAS services. Sheets of five and 25 cent coupons are available in book form of $5, $10, $25 or any amount desired from the Special Publications Dept. Scrip may be ordered by foreign and domestic members and nonmembers.

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IAS News Notes (Con't.)

THE IAS LIBRARY at National Headquarters is now receiving more than 400 periodicals, from which articles of interest to engineers and scientists are abstracted. These, together with abstracts of current technical reports, appear in the AERONAUTICAL REVIEWS section and the INTERNATIONAL AERONAUTICAL ABSTRACTS (yellow pages). The original material is available on loan to IAS members throughout the United States and Canada.

LIBRASCOPE, INCORPORATED, manufacturer of computer and control devices for aircraft and missiles, has joined the Institute as a Corporate Member. The firm is located at 808 Western Avenue, Glendale, California.

THE INSTITUTE invites applications for another two-year Fellowship in Flight Test Engineering. Forms may be had by writing to Flight Test, Institute of the Aeronautical Sciences, 2 East 64th Street, New York 21, N. Y. The letter requesting forms must be endorsed by a sponsoring reference.

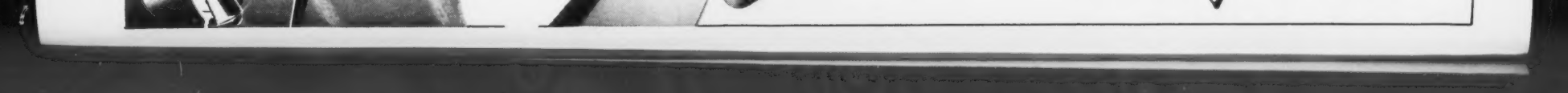
BEGINNING JANUARY, 1958, subscription rates for the Review will be $5.00 a year in the U. S. and possessions, and $6.00 a year in foreign countries including Canada. The price revision, first since the Review was founded in 1934, reflects rising production costs and a several-fold increase in content. Single copy price remains at $0.50.

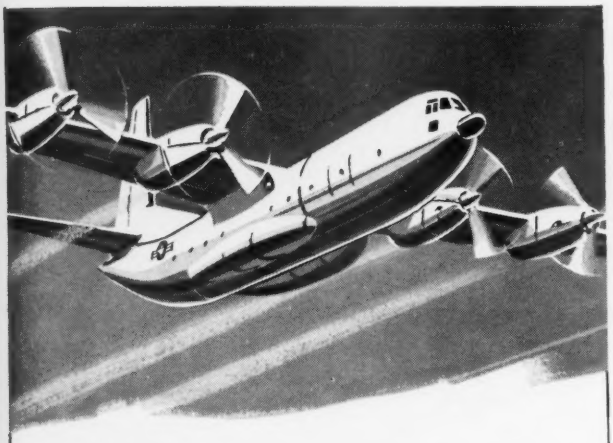
NATIONAL MEETINGS CALENDAR

Aug. 5-10	National Naval Aviation Meeting, U. S. Grant Hotel, San Diego, California.
Sept. 1-15	Sixth Anglo-American Aeronautical Conference, Royal Aeronautical Society and IAS, London and Folkestone, Great Britain.
Oct. 21-22	Canadian Aeronautical Institute-IAS Meeting, Montreal, Canada.
Nov. 7-8	Weapons System Management Meeting, Statler-Hilton Hotel, Dallas, Texas.
Dec. 17	Wright Brothers Lecture, Washington, D. C.
1958	
Jan. 27-31	Twenty-Sixth Annual Meeting, Sheraton-Astor Hotel, New York.
September	First International Congress, International Council of the Aeronautical Sciences, Madrid, Spain.

SECTION MEETINGS CALENDAR

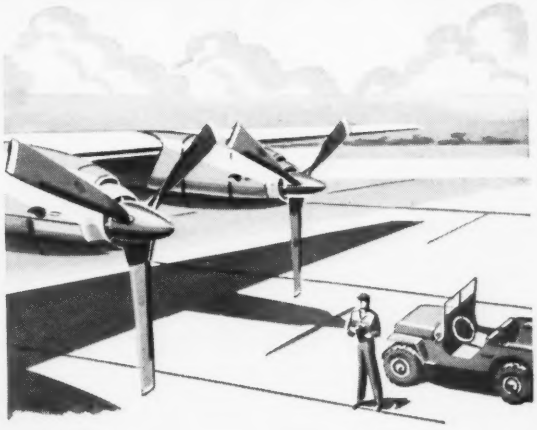
Aug. 13	Los Angeles Section: Specialist Meeting, IAS Building, 8 p. m. "A Glance at the Spectrum of High Speed Power Plant" by A. Charwat.
Aug. 27	Los Angeles Section: Specialist Meeting, IAS Building, 8 p. m. "Controlled Thermonuclear Reactions" by C. L. Critchfield.

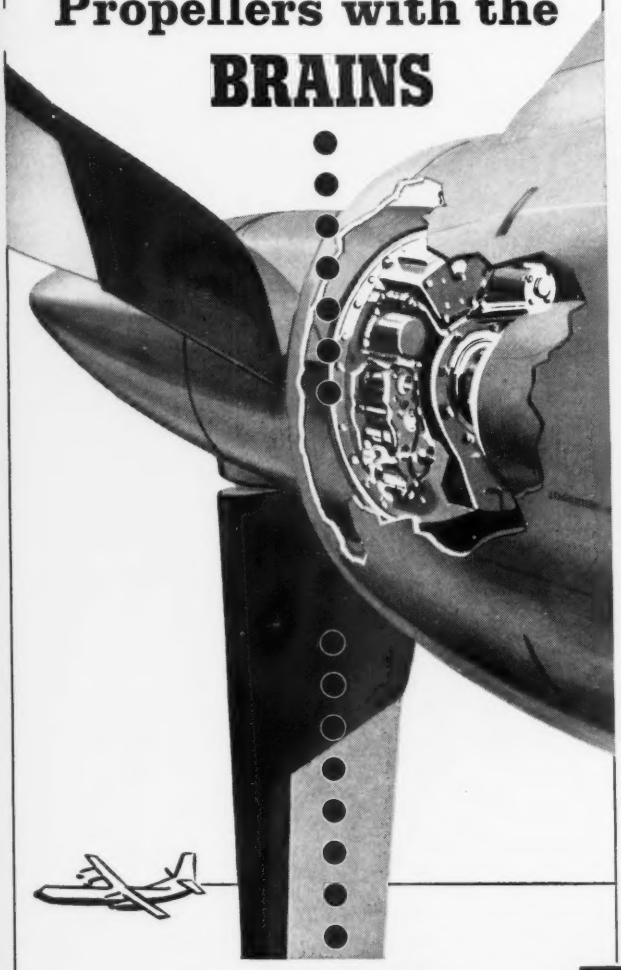




Curtiss-Wright TURBOLECTRICS

Propellers with the BRAINS





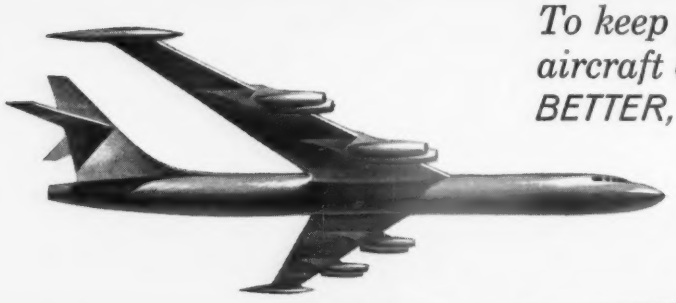
Converting the power of the new gas turbine or "turboprop" aircraft engines into useful thrust is a most exacting assignment for the time-honored propeller. It has to handle just about double any previous power . . . smooth out fast accelerations characteristic of these engines . . . control their power by the subtlest amount of pitch change on the blades . . . reverse to slow down and stop the momentum of some hundred tons of airplane.

With electromechanical brains for precise control . . . and with tough, one-piece extruded steel blades to handle unprecedented horsepower . . . Turbolectrics convert the basic operating efficiency of the turboprop into *flying* efficiency.

A leader in powerplant design, Curtiss-Wright also leads today in translation of turbine power into useful propeller thrust.

and BRAWN to TAME A TURBINE

PROPELLER DIVISION
CURTISS-WRIGHT
CORPORATION • CALDWELL, N. J.



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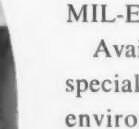
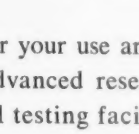


Hi-Temp Manual & Solenoid Operated Valves



Electric Motor Driven Hydraulic Power Packages

IAS News

A Record of People and Events of Interest to Institute Members

First International Congress of Aeronautical Sciences Slated for Madrid in September, 1958

New Worldwide Aeronautics Organization Formed in Paris

THE INTERNATIONAL Council of the Aeronautical Sciences has announced its first International Congress of Aeronautics, to be held in Madrid, Spain, in September, 1958.

This was decided by the Provisional Council of the new organization at its initial meeting in Paris on May 30. Sixteen representatives of ten nations met to form this first worldwide organization whose specific goal is to extend collaboration in all scientific areas pertaining to mechanical flight. Congresses will take place in other countries biennially.

Roll of IAS

The IAS, as the representative society in the United States for aeronautical scientists, engineers, and technical specialists, will act as permanent secretariat of the ICAS and provide the operating staff.

Funds toward the support of the ICAS are being made available through the Institute by utilization of a substantial donation by Harry Guggenheim, an IAS Honorary Fellow whose philanthropies in the interest of aeronautical research and development are well known.

In Mr. Guggenheim's honor, the ICAS has established the Daniel and Florence Guggenheim International Memorial Lecture. It will be presented by one of the world's outstanding aeronautical scientists at each International Congress.

Every country in the world that has an organized society dedicated to the advancement of the aeronautical sciences will be invited to participate in the ICAS without regard to military or political interest.

Theodore von Kármán, world-renowned aerodynamicist and teacher, and Chairman of the Advisory Group for Aeronautical Research and Development of NATO, was elected Honorary President and permanent member of the Council.

France's Maurice Roy, Director, Office National d'Etudes et de Recherches Aéronautiques, was elected Chairman of the Provisional Council's Executive Committee.

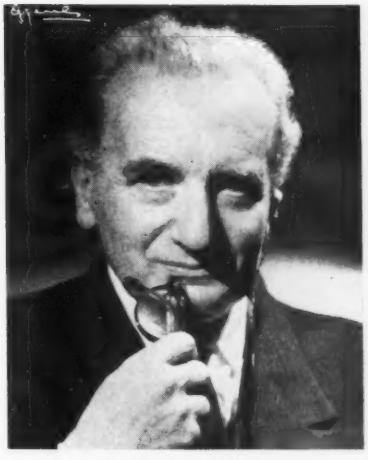
ICAS Provisional Council

The 16 delegates at the ICAS organizational meeting who make up the Provisional Council are as follows:

Canada: John J. Green, Defence Research Member, Canadian Joint Staff.

France: Charles de Faget, Office National d'Etudes et de Recherches Aéronautiques; Jules Jarry, President, Association Française des Ingenieurs et Techniciens de l'Aéronautique; and Maurice Roy, Director, ONERA.

Maurice Roy
Chairman, ICAS Provisional Council
Executive Committee



Theodore von Kármán
Honorary President, ICAS

Germany: Hermann Blenk, President, Wissenschaftliche Gesellschaft für Luftfahrt.

Great Britain: A. M. Ballantyne, Secretary, The Royal Aeronautical Society; and E. T. Jones, General Director of Technical Development, Ministry of Supply.

Holland: A. J. van der Maas, Professor of Aeronautics, Delft Technical University.

Italy: Guiseppe Gabrielli, Director, Divisione Aviazione FIAT.

Spain: Col. Antonio Perez-Marin, Secretario General, Instituto Nacional de Tecnica Aeronautica.

Sweden: Bo K. O. Lundberg, Director, Aeronautical Research Institute of Sweden.

Switzerland: R. Greinacher, Chief Aviation Section, Service Technique Militaire.

U.S.A.: Hugh L. Dryden, Director, National Advisory Committee for Aeronautics; S. Paul Johnston, Director, IAS; Theodore von Kármán, Chairman, AGARD, of NATO; and Frank L. Wattendorf, Director, AGARD, of NATO.

First Choice in Speed Controls

The winding of wire on toroidal cores is a precision machine operation — one requiring COMPLETE control from beginning to end. Typical rheostat or inductor production may call for use of wire ranging in size from No. 25 to 35; and on occasion the job may require work with heavy wire ribbon ¼" wide or more.

The high degree of flexibility required is best provided by the Variac Motor Speed Control, specifically designed for machine tool and other exacting manufacturing operations. Continuous speed control over wide ranges — full torque at very low as well as at very high speeds — and an absolute minimum of torque pulsation or "jumping" which often causes rejects — are but a few of the features incorporated in this equipment to make it one of the finest motor speed controls on the market today.

G-R Variac Motor Speed Controls will operate d-c shunt, compound, or series motors from a-c lines, providing all the advantages of d-c motor performance with the convenience of operation from readily available a-c power. Units are available with ratings ranging from $^1/_{15}$ to 1½ hp, in either rugged industrial-type cabinets or as stripped-down models for assembly as integral parts of other equipment. Prices (less motor) range from $85 to $380 for cabinet models; $72 to $358 for basic stripped-down units. Quantity discounts apply.

Write for complete information

Versatility — the G-R Control operates at high speeds for wire winding, is equally useful for work with heavy ribbon at considerably slower speeds — same control does both jobs without need for pulley or gear changing.

Full-Torque Starts permit operator to watch and carefully control work at slow speeds when correct wire pitch and space distribution must be determined.

Smooth Acceleration with *constant* torque eliminates sudden pulling of wire and possible breaking or flexing.

Fast Stopping permits automatic motor shut-off exactly to the turn — extremely useful in many machine operations.

Motor Reversal with flick of switch — extremely convenient when magazine of the winding machine must be loaded.

Long Life with minimum maintenance — no electron tubes; built in overload protection prevents motor burnout.

These characteristics have proven useful to many. They can also be of service to you.

The Rex Rheostat Company
has experimentally controlled its winding machines with a wide variety of both electrical speed controls and mechanical devices. None were found to compare in performance to the G-R Control now specified for plant-wide use. Production-control engineers and machine operators alike appreciate this Control's ease of handling and high production efficiency.

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All G-R Products are now covered by a *2-Year Warranty*

Jerome C. Hunsaker to Receive RAeS Gold Medal

Society's Highest Honor to Be Awarded During Anglo-American Conference

Time Schedule for Technical Papers, Wives' Program Announced

JEROME C. HUNSAKER (HF) has been named by the Royal Aeronautical Society to receive its highest award at the Wilbur Wright Lecture during the Sixth Anglo-American Aeronautical Conference.

On September 13, Dr. Hunsaker will be awarded the Society's Gold Medal "for his contributions to aeronautical research and education, including his inspired chairmanship of the National Advisory Committee for Aeronautics." This is the highest honor which the Society can confer for work of an outstanding nature in aeronautics.

The RAeS also has announced the election of the following Americans as Fellows of the Society:

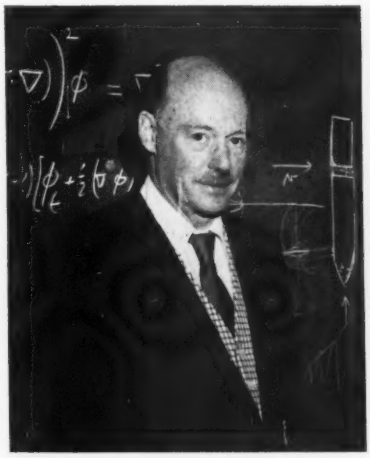
Edward H. Heinemann (F), Chief Engineer, Douglas Aircraft Company, Inc., El Segundo Division; S. Paul Johnston (F), Director, IAS; Jerome F. Lederer (F), Director, Flight Safety Foundation, Cornell-Guggenheim Aviation Safety Center; John C. Leslie (F), Administrative Vice-President and Director, Pan American World Airways, Inc.; Alfred S. Niles (F), Professor of Aeronautical Engineering, Stanford University; Courtland D. Perkins (AF), Chief Scientist, USAF; Rear Adm. Selden B. Spangler (F), Commander, U.S. Naval Air Development and Material Center; and John Stack (F), Assistant Director, Langley Aeronautical Laboratory, NACA.

Other members of the Institute who were elected Fellows in the Society are Douglas W. Holder (AF), Senior Principal Scientific Officer, Aerodynamics Division, National Physical Laboratory, Teddington, Great Britain; and Paul R. Owen (AF), Professor of Mechanics of Fluids and Director of Laboratory, Manchester University, Great Britain.

More Conference News

Plans for the Conference are continuing, and the RAeS has announced that preprints of technical papers will be available in looseleaf form before they are presented. Final publication will be in a bound volume (*Proceedings*) and will incorporate with the discussions any modifications and additions made by the author at the time of the formal delivery of the paper.

Clark B. Millikan (HF), Director, Guggenheim Aeronautical Laboratory and Southern California Cooperative Wind Tunnel, California Institute of Technology, will deliver the forty-fifth Wilbur Wright Lecture in London. Dr. Hunsaker delivered this lecture in 1920.



Jerome C. Hunsaker (HF)
Recipient of 1957 RAeS Gold Medal

Technical Paper Schedule

The 16 technical papers scheduled will be presented at the Metropole Hotel, Folkestone, from Monday, September 9, to Thursday, September 12. There will be no parallel sessions during these 4 days, and it will be possible to attend all the lectures. (All lectures will be 1½ hours long.) Papers will be presented in the following order:

Monday: 9:15 a.m.—"NACA Research on VTOL and STOL Airplanes"; 11:00 a.m.—"Small Nuclear Power Units"; 2:00 p.m.—"Control of Supersonic Propulsion Systems"; 4:00 p.m.—"The Electrical Control of Power Plants."

Tuesday: 9:15 a.m.—"Some Aspects of Kinetic Heating of Aircraft Structures"; 11:00 a.m.—"Nine Years' Experience With Titanium"; 2:00 p.m.—"The Use of High-Temperature Nonmetallic Materials"; 4:00 p.m.—"Blast Loads on Aircraft Structures."

Wednesday: 9:15 a.m.—"Safety in Relation to Structural Damage"; 11:00 a.m.—"An Appraisal of Aeroelasticity in Design, With Special Reference to Aeroelastic Stability"; 2:00 p.m.—"The Presentation of Information by Aircraft Instruments"; 4:00 p.m.—"Increased Usable Lift Through Boundary-Layer Control."

Thursday: 9:15 a.m.—"The Role of Experimental Hyperballistics in the Development of Future Airplanes and Missiles"; 11:00 a.m.—"Future Aerodynamic Shapes"; 2:00 p.m.—"Aerodynamic Effects of Boundary-Layer Unsteadiness"; 4:00 p.m.—"The Human Pilot as an Aircraft Operator."

Wives' Program

The RAeS has set up a special London program for wives of engineers attending the Conference. Applications for this have been mailed. The schedule lists the following activities:

August 31 and September 1 (morning): Registration at 4 Hamilton Place, London. *September 2:* Tour of London, including Thames River boat trip and theater in the evening. *September 3:* Visit to Windsor Castle and tea with Lady Edwards. *September 4:* Visit to the Colleges of Oxford University. *September 5 and 6:* Visit to Stratford-On-Avon, theater, overnight at Stratford, Warwick Castle, and Kenilworth or Evesham, Cheltenham Stow-in-the-Wold, Aylesbury.

The second week's program at Folkestone, indicated on the delegate's application form, lists the following functions to which wives are invited: reception at the Metropole Hotel, evening of September 9; Mayor's reception, evening of September 11; dinner, evening of September 12; Wilbur Wright Lecture (London), evening of September 13; and a garden party at Wisley Aerodrome, morning of September 15.

Six Institute Members In New Engineering Firm

A group of aeronautical engineers and research scientists, six of whom are IAS members, have formed the Research Engineering Services Corporation (RESCO) to engage in contract engineering activities.

The six IAS members are Willi F. Jacobs (M), RESCO President; Peter Fielding (M), Vice-President; Gordon R. Forbes (M), Wilfred C. J. Garrard (M), Nils-Olof Olesten (M), and John H. Paterson, (M).

The firm has announced that its primary goal will be to make available to general industrial groups in this country the technological advances pioneered throughout the field of aeronautics. RESCO will provide an organized channel for the commercial application of aeronautical advances to other fields of engineering, according to the firm's president.

The company can be reached at P.O. Box 467, Sandy Springs, Ga.

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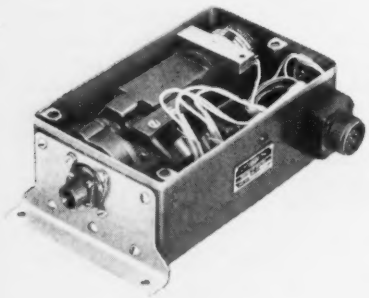
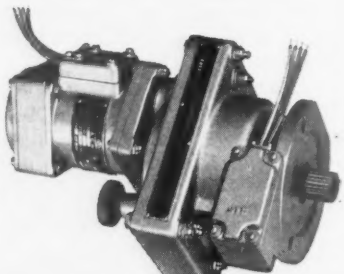
Type: D-818 Leading Edge Flap Actuator; **Weight:** 20.5 lbs. **Normal Operating Load:** 6,000 lbs.; **Maximum Operating Load:** 12,000 lbs. **Ultimate Static Load:** 24,000 lbs.; **Stroke:** 3.15"; **Rate of Travel:** .33" per second; **Amperes:** 3 amps at 480 cycles on 200 volts at the 6,000 lbs. load. **Meets Mil. Specs.:** MIL-A-8064 for actuators, MIL-M-7969A for motors.

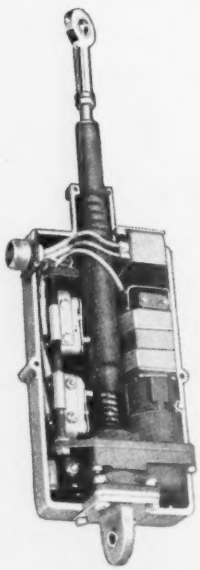
EEMCO's low-weight, high-power linear and rotary actuators are designed and engineered to give consistent, top-efficiency performance under the most extreme environmental conditions. The widespread use of these rugged components can only mean that the entire aircraft industry recognizes their built-in accuracy and reliability. EEMCO, in turn, recognizes the importance of adhering to strict production schedules, and will continue to assure prompt delivery.



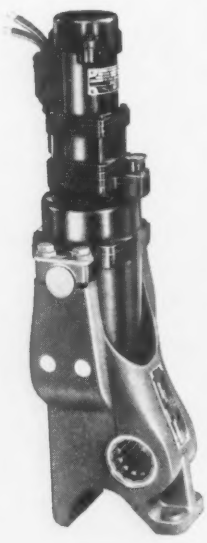
Type: D-892 Power Package; **Size:** 7⅛" x 4¾₆" x 2¾". **Output:** 28 volts D.C., 1390 RPM at take-off shaft, 18 inch-oz. torque. **Weight:** 3⅜ lbs.; Operative in ambient temperatures to 250° F. **Meets Military Specifications:** MIL-A-8064 for actuators, MIL-M-8609 for motors.



Type: D-868 Rotary Actuator; **Weight:** 9⅞ lbs. **Power:** 200 volt, 400 cycle, 3-phase motor. **Ambient Temperature Range:** −65°F. to +400°F.; **Shaft Torque Limit:** Adjustable. **Load:** 1,650 inch-lbs. maximum to approx. 2 RPM on 1.5 amps. **Meets Military Specifications:** MIL-E-7894 and MIL-A-8064.



Type: D-607 Transport Door Actuator; **Weight:** 4.5 lbs. **Stroke:** 6.25"; **Operating Load:** 450 lbs.; **Ultimate Static Load:** 7150 lbs. tension; **Speed of Stroke:** under 450 lb. load—0.3" per second. **Size of Power Section:** 2¼" x 4½" x 8¾₆". **Meets Mil. Specs.:** MIL-A-8064 for actuators, MIL-M-8609 for motors.



Type: D-822 Trailing Edge Flap Rotary Actuator; **Weight:** 35 lbs. **Normal Operating Load:** 26,000 inch-lbs. **Maximum Operating Load:** 52,000 inch-lbs. **Ultimate Static Load:** 75,000 inch-lbs.; **Travel:** 45 degrees at .625 RPM; **Amperes:** 4 amps at 26,000 inch-lbs. at 480 cycles on 200 volts. **Frequency Range:** 380 to 420 cycles. **Meets Mil. Specs.:** MIL-A-8064 for actuators, MIL-M-7969A.

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Rocket Plane Test Pilot Wins 1957 Chanute Award

Lt. Col. Frank K. Everest, Jr., Honored

For Development of Bell X-2 Flight-Test Techniques

THE INSTITUTE'S 1957 Octave Chanute Award has been presented to 37-year-old Lt. Col. Frank K. Everest, Jr., "for his outstanding contributions to the development of rocket-powered aircraft flight test techniques."

Colonel Everest, a native of Fairmont, W.Va., received the award at the IAS National Summer Meeting in Los Angeles. He was the first pilot to fly the Bell X-2 rocket-driven research aircraft.

The first powered flight of the X-2 was made on March 24, 1956. The purpose of this flight and seven subsequent flights made by Colonel Everest was to develop an engineering technique and pilot skill which would allow the aircraft to be flown at its full potential speed and altitude. His engineering knowledge, flying skill, and flight-test experience enabled him to evaluate difficulties encountered and to develop new techniques to avoid known areas of difficulty.

On July 23, 1956, he completed his eighth and final powered flight, demonstrating optimum engineering technique and outstanding flying skill and reaching a greater flight speed than had ever been attained before.

Colonel Everest entered aviation cadet training in November, 1941, and received his wings in July, 1942. After further training, he flew as a fighter pilot in North Africa, Sicily, and Italy, completing 94 combat missions before returning home in March, 1944.

He served as an instructor in a fighter squadron stationed at Venice, Fla., until October, 1944, when he volunteered to return to combat duty and was assigned to the China-Burma-India theater of operations. As a Squadron Commander in the CBI he flew another 67 combat missions before being shot down by ground fire on May 27, 1945. He remained a prisoner until the end of World War II hostilities.

During the immediate postwar period he was assigned to the Flight Test Division at Wright-Patterson AFB where for 4 years he participated in aircraft tests. He flight tested the Bell X-1, reaching an altitude of 73,000 ft., and the XF-92, the first delta wing aircraft.

In May, 1950, Colonel Everest was made Chief, Flight Test Operations Division, at Edwards AFB Flight Test Center. In this assignment he participated in flight tests on the X-1, X-1B, D-558, XF-92, X-3, X-4, X-5, F-100, F-101, F-102, F-104, and the X-2 aircraft. He set a new world's 15-km. speed record in October, 1953, flying the North American F-100 Super Sabre. His most recent assignment was as a student at the Armed Forces College, Norfolk, Va. He is an engineering graduate of West Virginia University.

Lt. Col. Frank K. Everest, Jr., USAF
Winner of the 1957 Octave Chanute Award

The IAS award, a certificate and honorarium, is given annually for "a notable contribution made by a pilot to the aeronautical sciences." Last year's winner was A. M. "Tex" Johnston, Chief of Flight Test, Boeing Airplane Company.

Kincheloe Awarded Mackay Trophy
For 126,200-Ft. Climb in Bell X-2

Air Force Chief of Staff, Gen. Nathan F. Twining, has awarded the 1956 Mackay Trophy to Capt. Iven C. Kincheloe, Jr. (A), an experimental Flight Test Officer at Edwards AFB, Calif.

Captain Kincheloe received the trophy for flying the Bell X-2 rocket-powered research aircraft to a height of 126,200 ft. on September 7, 1956. Through his flying skill he mastered the highly exacting climb technique necessary for taking full advantage of the short fuel duration of the aircraft, the Air Force said.

The Mackay Trophy is awarded annually for the most meritorious flight by an Air Force person or organization. The citation states that Captain Kincheloe "with outstanding courage pressed well beyond the highest altitude ever before achieved in a piloted airplane."

Capt. Iven C. Kincheloe, USAF

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American Helicopter Society's Thirteenth Annual Forum

1,000 Hear Courtland D. Perkins Give Honors Night Address

17 Technical Papers Delivered, 30 Helicopters in Air Show

THE AMERICAN Helicopter Society's 13th Annual Forum in Washington, May 8–11, drew a record turnout for the technical sessions, the Honors Night reception and dinner, and the Helicopter Display.

Some 1,000 members and guests heard Courtland D. Perkins, Chief Scientist, USAF, deliver the Honors Night address. He discussed his thoughts on requirements of research and development programs covering helicopters, VTOL, and STOL aircraft, pointing up where the Armed Forces' areas of interest lie.

The Dr. Alexander Klemin Award was presented posthumously to Major Wayne W. Eggert, Experimental Helicopter Test Pilot, USAF, for his contributions through flight test to the rotary wing industry. Col. A. T. Culbertson accepted the award for Mrs. Eggert, who was the Society's guest at the Honors Night Dinner.

Robert L. Suggs, President, Petroleum Helicopters, Inc., was recipient of the Kossler Award for the most outstanding practical application of the helicopter in the petroleum industry.

Two Honorary Fellowships were awarded to Jean Ross Howard, Assistant to the Director, AIA Helicopter Council, for her continued support of the Society as its Secretary during the early period of organization; and to S. Paul Johnston, for his guidance and assistance in the organization and development of the Society as Director of the Institute of the Aeronautical Sciences with whom the Society has been affiliated since 1951.

A total of 17 technical papers were presented at four sessions. These are available to members at a rate of $5.00 and to nonmembers for $7.50 by writing the AHS Headquarters, 2 East 64th Street, New York 21, N.Y.

Luncheon speaker Arthur Godfrey related his experiences in Africa where he flew a Bell 47G helicopter.

The Annual Air Show held at Anacostia Naval Air Station featured almost 30 different types of helicopters, including the French Alouette, DeLackner Aerocycle, Sikorsky H-37, and the Hiller XROE.

New Officers

New AHS officers for the 1957–1958 term are: President—Don R. Berlin, Board Chairman and President, Vertol Aircraft Corporation; Vice-Presidents—New England, Michael J. Theodore, Sikorsky Aircraft Division, United Aircraft Corporation; Mideast, William E. Cobey, President, Transcendental Aircraft Corp.; Southeast, Donald M. Thompson, Office of Research and Development, Army Transportation Corps; Midwest, Lloyd R. Novak, McDonnell Aircraft Corporation; Southwest, Robert R. Lynn, Bell Helicopter Corp.; Western, Robert J. Sullivan, Hughes Tool Co., Aircraft Division. Claude O. Witze, Military Editor, *Aviation Week*, was elected Secretary, and Marvin D. Marks, Chief, Rotor Research, McDonnell Aircraft Corporation, elected Treasurer.

Dr. Perkins, referring to current enthusiasm for VTOL development, said in effect that manufacturers should not put all their eggs in one basket. He said, "It appears to me that many people in the helicopter field have felt that the day of the helicopter is about over and that they are about to be supplanted by the more sophisticated VTOL and STOL configurations presently under study in our research and development program.

"There are many operational requirements of the Armed Forces that can be resolved more efficiently by the helicopter and there is no question that the Armed Forces will continue to use them quite actively.

"The use of the gas turbine combined with a sophisticated program to improve the shortcomings of the helicopter will extend its usefulness along many lines and again I would encourage this Society to be very vocal in support of this type of development."

Jean Ross Howard was congratulated by Charles Seibel, outgoing AHS President, after receiving an Honorary Fellowship in the Society. Harry Lounsbury, AHS Executive Secretary, looks on.

Courtland D. Perkins, USAF Chief Scientist, was Honors Night speaker at the AHS's 13th Annual Forum.

Dr. Perkins did not discount the need for VTOL and STOL aircraft and said it was not practical to try to solve all logistic cargo airplane problems with one of these types alone.

Technical Papers

The following technical papers were delivered at the Forum:

Helicopter Design and Development: "Metal Rotor Blade Development" by C. H. Linnabery, Bell Helicopter Corporation, "Closing the Loop on Automatic Stabilization Equipment" by Walter Gerstenberger, Sikorsky Aircraft Division; "Test Experience With the T-58 Engine" by N. N. Davis, General Electric Company; "T-53 Flight Test and Test Stand Results" by Leroy A. Howard, Lycoming Division AVCO Manufacturing Corporation.

VTOL Design and Development: "The Limitations of a Wing for Low-Speed Flight" by J. B. Nichols, Hiller Helicopters; "Compromises Associated With VTOL and STOL Propellers" by Robert A. Rogers, Aeroproducts Operations, General Motors Corporation; "Military Aspects of VTOL Aircraft Development" by Lt. Col. John L. Klingenhagen, USA, Office of Assistant Secretary of Defense for Research and Development; "Designing for Crash Survival in VTOL Aircraft" by A. Howard Hasbrook, Aviation Crash Injury Re-

(*Continued on page 102*)

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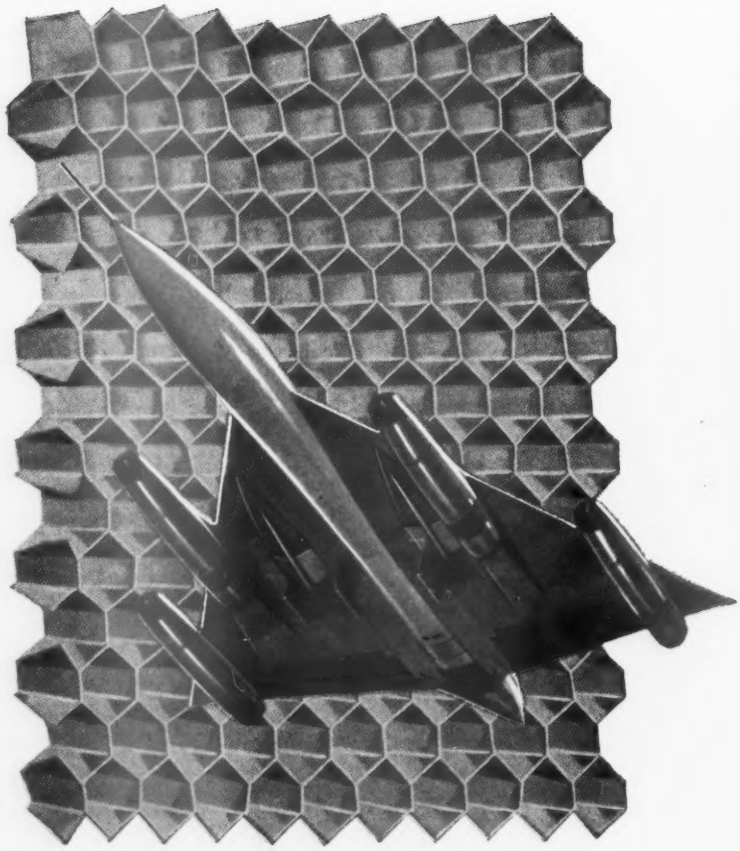

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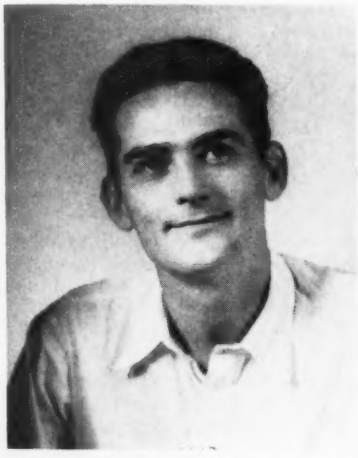
Fifth Southwestern Student Conference Sponsored by Texas Section, Four Aircraft Firms

W. Carson Lyons, Jr., University of Texas, won first prize in the Graduate Division.



William D. Oliver, University of Colorado, won the Undergraduate first prize.

THE FIFTH Southwestern Regional Student Conference was held in Fort Worth, April 25–27, in spite of the heaviest rains in 7 years in that area.

Sponsored by the Institute's Texas Section, the Conference opened formally on Thursday morning, April 25, with a welcoming address by R. J. Patton, Texas Section Chairman. E. W. Robischon, IAS Western Region Manager, represented IAS National Headquarters, and Ted Dansby, Student Paper Competition Chairman, outlined the program and judging procedures.

Later, the first luncheon meeting was held for students, faculty members, and Section members. Bartram Kelley, Vice-President—Engineering, Bell Helicopter Corporation, spoke on his firm's accomplishments. He stressed the diversity of problems that aircraft companies in general are facing and the dynamic problem in helicopter work. After the luncheon the first group of undergraduate papers was presented.

Both undergraduate and graduate papers were presented at Friday morning's session. H. F. Marx, Temco Aircraft Corporation, and W. C. Schoolfield, Chance Vought Aircraft, Inc., were cochairmen.

Friday's luncheon featured a brief description of activities at Temco by I. N. Palley, Vice-President—Engineering. Included in his presentation was a series of humorous slides on the definition of terms used in the aircraft and missile industries. "The Engineering Personality" was discussed by F. W. Davis, Chief Engineer, Convair, A Division of General Dynamics Corporation.

R. C. Donovan of Chance Vought was Chairman of the Friday afternoon session which concluded the Student Paper Competition. The Conference continued Friday night with the Annual Faculty-Industry Smoker, an open discussion meeting.

Areas covered were the need for teaching high school level material in some colleges, lack of high school science teachers, trade school training as opposed to college preparatory training, and guidance programs.

On Saturday students and faculty visited facilities of Temco, Chance Vought, Bell, and Convair, in that order. The field trip included a first-hand view of the B-58 Hustler and a flight demonstration of the Bell 47J helicopter.

G. G. Quarles, Scientific Consultant to the Army Ballistic Missile Agency, was guest speaker at the Honors Night banquet Saturday evening. He discussed the potential for space travel and showed movies and slides of current Army missiles and proposed space vehicles. He discussed a variety of propulsive methods.

Mr. Robischon and Mr. Dansby presented awards to winners of the Student Paper Competition. Graduate division first prize went to M. Carson Lyons, Jr., University of Texas, for his paper "The Design and Laboratory Evaluation of an Acceleration Insensitive Skin Friction Balance."

W. D. Oliver, University of Colorado, won undergraduate first prize for his paper "The Development of Vacuum Evaporated Conduction Heaters for the Simulation of Aerodynamic Loads on Heated Structures."

Second and third prize winners were J. B. LeClaire, University of Kansas, and D. R. Moore, University of Texas.

TED DANSBY, *Chairman*
Student Paper Competition

Gilford G. Quarles *(left)* conferring with R. J. Patton.

Students and faculty members visited Temco Aircraft Corporation's facility on a field trip. Other visits were made to facilities of Convair, Chance Vought, and Bell Helicopter.

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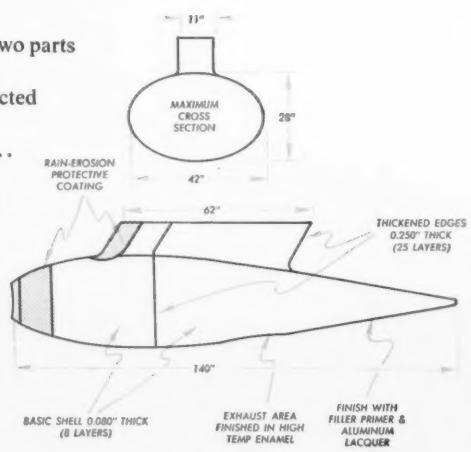

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St. Louis Section Sponsors Regional Student Conference
19 Technical Papers Entered; 150 Attend Awards Banquet

Honors Night speaker Ethan A. H. Shepley, Chancellor, Washington University, and winners of the Student Paper Competition during the St. Louis Regional Student Conference. Winners from *left to right* are Albert W. Black, Washington University; Joseph Tsu Chieh Liu, University of Michigan; James Bede, University of Wichita; Mr. Shepley; Nancy L. Smith, University of Kansas; Gary Griffith, Kansas; and Donald D. Campbell, Wichita.

A TOTAL OF 19 technical papers from five midwestern colleges were entered in the St. Louis Regional Student Conference, April 24–26. The Institute's St. Louis Section was Conference sponsor.

Six winning papers were selected and delivered at the Student Paper Competition on April 25. First prize went to Gary Griffith, University of Kansas, for "A Comparison of External and Internal Compression Inlets With Respect to Pressure Recovery."

Nancy L. Smith of the University of Kansas won second prize for her paper "Calculation of Boundary-Layer Characteristics for a Two-Dimensional Supersonic Wind-Tunnel Nozzle."

Third prize was awarded to Donald D. Campbell, University of Wichita, for "The Free-Stream Static Pressure Error at a Single Flush Orifice in a Sinusoidally Waved Wall."

Honorable mention and best oral presentation prizes went to James Bede, University of Wichita, for his paper on "Steam JATO." Other honorable mention prizes were won by Albert W. Black, Washington University, for "An Electrical Analog for Heat Conduction"; and by Joseph Tsu Chieh Liu, University of Michigan, for "Supersonic Flow Over Inclined Slender Bodies of Revolution With Magnus Effect."

Some 50 students, faculty members, and St. Louis Section members attended this competition.

Awards and travel and living expenses were provided by the Minta Martin Aeronautical Student Fund and the following firms: Aero Engineering Co.; Allison Division, General Motors Corporation; Emerson Electric Manufacturing Co.; General Electric Company; Harris-Hanson Co.; McDonnell Aircraft Corporation; Sverdrup & Parcel, Inc.; and Westinghouse Electric Company.

Some 150 guests attended the Honors Night Banquet and Awards Dinner on April 25 at Schneithorst's Restaurant. Toastmaster was S. N. McDonnell of McDonnell Aircraft. Kendall Perkins, Vice-President—Engineering, McDonnell, and John I. Parcel presented awards to winners.

Ethan A. H. Shepley, Chancellor, Washington University, spoke on "Education in a Period of Technological Growth."

The Conference closed April 26 with visits to facilities of McDonnell Aircraft Corporation and the Emerson Electric Company.

Schools and participants in the Student Paper Competition were: University of Kansas—Jim Hull, Carl Kulp, Paul McWilliams, Jr., Leonard Rohrbough, Richard Davis, Gary Griffith, Nancy L. Smith, Gretchen Zimmerman, Abraham Gallas, Ronald Herman, Robert Huston, and Ronald Wheeler; University of Kentucky—J. D. Igleheart; University of Michigan—Bert Hilburger and Joseph Tsu Chieh Liu; Washington University—Thomas Littman and Albert W. Black; University of Wichita—Donald Campbell and James Bede.

Arrangements for the Conference where handled by the St. Louis Section Educational Committee and its Chairman P. T. Homsher.

PAUL T. HOMSHER
Chairman, Education Committee

Left: **James Bede, University of Wichita, is shown delivering his paper on "Steam JATO" complete with mock-up at the St. Louis Regional Student Conference. He won an honorable mention and the best oral presentation prize. Nineteen students from five different colleges participated.** ***Right:*** **Nancy L. Smith accepts second prize in the Student Paper Competition from Kendall Perkins, Vice-President—Engineering, McDonnell Aircraft Corporation. She is a student at the University of Kansas.**

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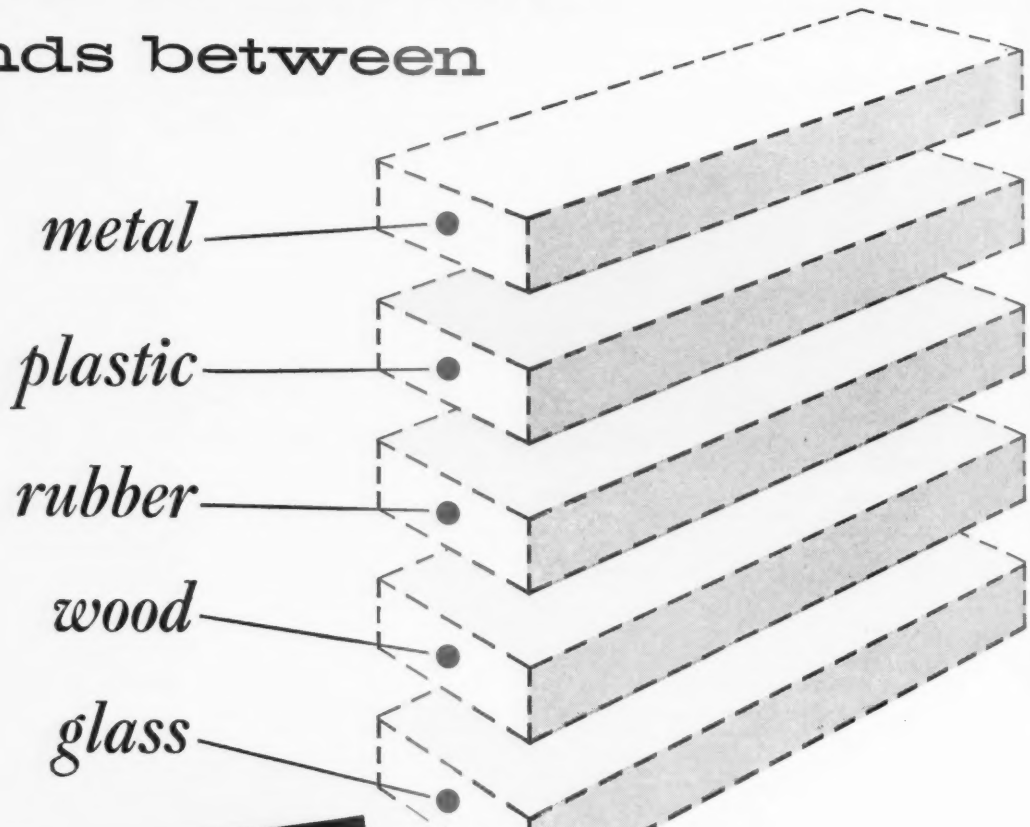

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Four Schools Compete for Technical Paper Awards at Indianapolis Regional Student Conference

The Second Annual Indianapolis Regional Student Conference was held April 8 during a snowstorm through which 65 members and students fought their way to Purdue University's Student Union Building, West Lafayette, Ind.

In spite of this unseasonable weather, some 50 conference participants visited Purdue's Aeronautical School, where a demonstration of cascaded airfoils in a smoke tunnel was seen.

The Student Paper Competition, sponsored by the IAS Indianapolis Section, featured contributions from the Aeronautical University, Kent State University, Tri-State College, and Purdue.

R. C. Binder, Vice-Chairman, Indianapolis Section, presided over the dinner meeting at which Paul E. Stanley presented awards for the winning papers. Dr. Stanley is Professor of Aeronautical Engineering at Purdue.

Three winners were announced. First prize went to David L. Clingman, Purdue; second to Richard C. Burnell, Kent State, and third prize was won by Thomas L. Kinsel, Aeronautical University.

Mr. Clingman delivered a paper on "An Experimental Determination of the Effects of Slotted Blades in Cascade Flow and Possible Application to Delay of Rotating Stall in Dual Flow Compressors." Mr. Burnell's paper was "Jet-Engine Noise Suppressors."

David L. Clingman, Purdue University, first-prize winner.

Robert Goulard, Purdue Graduate School, concluded the competition with "A Survey of Hypersonic Aerodynamics" in which he explained some of the problems encountered at high speeds and high temperatures. He also discussed how they complicate standard aerodynamic solutions of fluid flows.

James B. Cahill, *Acting Secretary*
Indianapolis Section

The Ramo-Wooldridge Corporation Is New Corporate Member

The Ramo-Wooldridge Corporation of Los Angeles is the 151st Corporate Member in the Institute. The firm's address is 5730 Arbor Vitae Street, Los Angeles 45, Calif.

Ramo-Wooldridge conducts research, development, and manufacturing operations in the field of electronic systems for commercial and military applications and in the field of guided missiles.

In the missile field the firm has responsibility for overall systems engineering and technical direction of the Intercontinental and Intermediate Range Ballistic Missile programs for the Air Force. In addition, the company conducts a program of basic research in aerodynamics and propulsion.

Institute Continues Growth: 28th Section Formed in Kansas City

Another mark was added to the Institute's scale of growth with the formation of a Kansas City Section by IAS members in that area.

The twenty-eighth Section of the Institute was organized by a steering committee headed by R. P. Kroon, Director of Research, Aircraft Gas Turbine Division, Westinghouse Electric Corporation. Mr. Kroon was toastmaster at the initial meeting on May 15.

Elected to the Advisory Board were Mr. Kroon, R. W. Rummel, A. S. Andes, and V. V. Schloesser.

Officers elected were Chairman—H. F. Faught, Manager, Advanced Development, AGTD, Westinghouse; Vice-Chairman—M. B. Fannon, Assistant Director, Flight Operations, Trans World Airlines; Secretary—J. R. MacPherson, Section Engineer, Installation, AGTD, Westinghouse; and Treasurer—Paul A. Hartline, Supervisor, Mechanical Engineering, TWA.

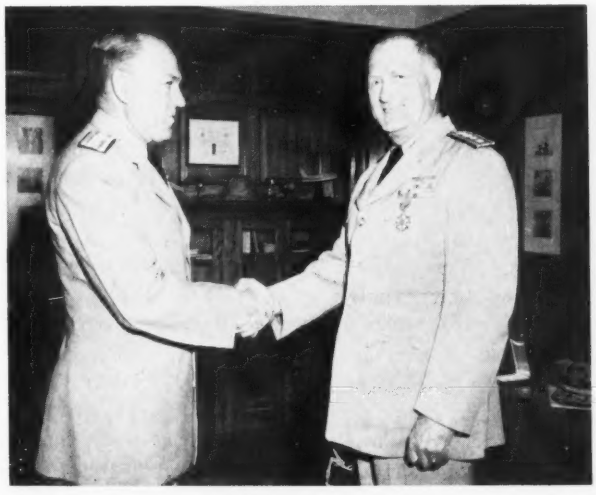
Applied Mechanics Congress Invites Research Papers

Brown University has announced that the Third U.S. National Congress of Applied Mechanics will take place June 11–14, 1958, at its Providence, R.I., campus.

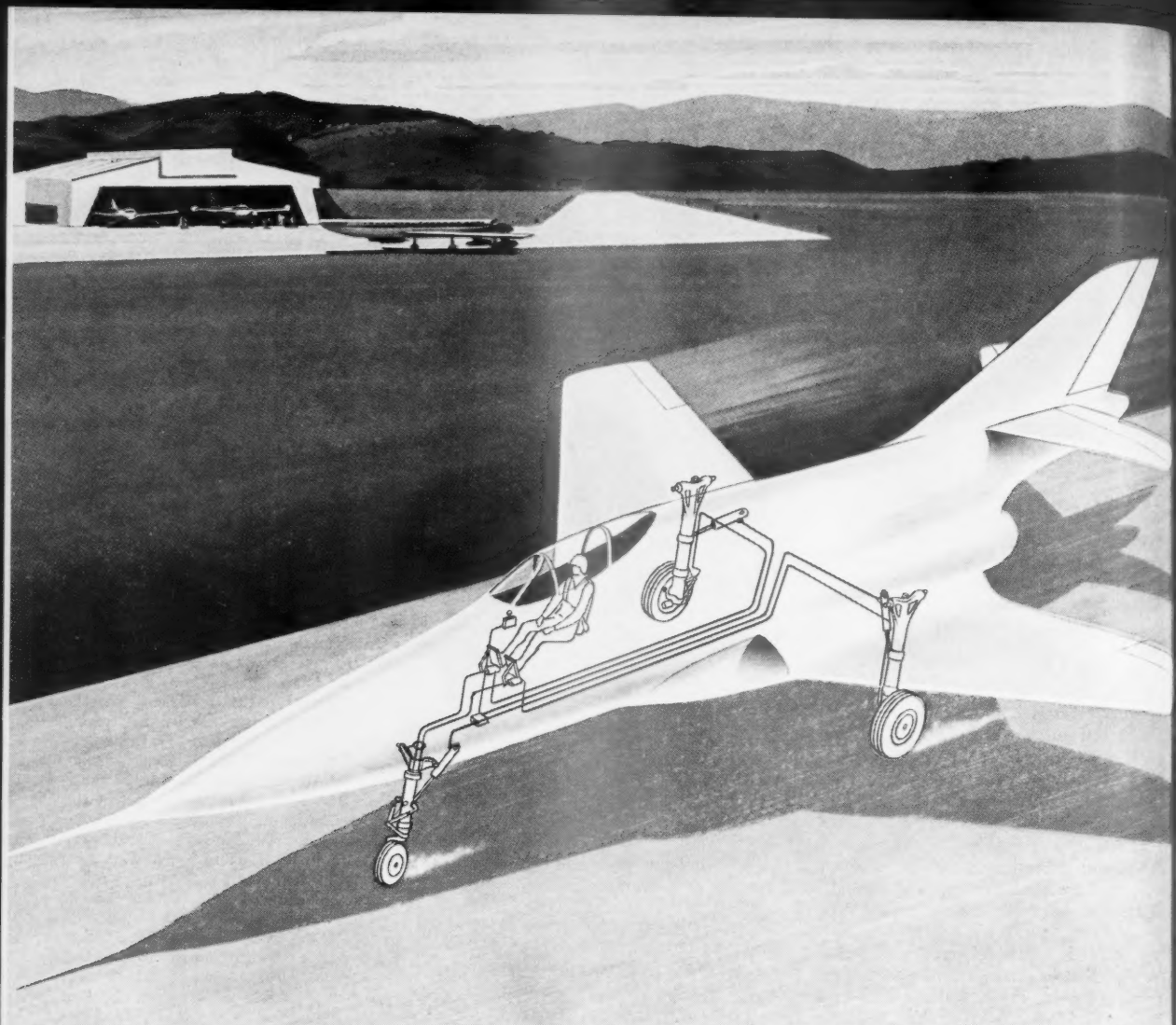
Congress officials have invited all research workers in the field to submit original experimental or theoretical contributions (in the form of papers) on applied mechanics, including mechanics of rigid bodies and deformable solids, mechanics of fluids and gases, thermodynamics, and heat transfer.

Complete papers and manuscripts must be submitted to the Chairman of the Editorial Committee before January 1, 1958: to be scheduled for presentation the final manuscript must have been accepted before May 1, 1958.

Papers will be grouped by subject, and 30 min. will be allotted for presentation and discussion of each paper. Inquiries may be addressed to Daniel C. Drucker, Secretary, Applied Mechanics Congress, Brown University, Box D, Providence 12, R.I.



Rear Adm. Delmer S. Fahrney, USN (Ret.), an Associate Fellow of the Institute (*right*), was the recipient of his second Legion of Merit medal for outstanding work in the development of experimental aeronautical equipment during World War II. His work resulted in a combat-equipped radio-controlled Assault Drone. Rear Adm. Ephraim R. McLean, Jr., Commandant, 4th Naval District, congratulated Admiral Fahrney at the District Headquarters where he is employed in a civilian capacity for the Naval Air Material Center.



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NEWS OF MEMBERS

▸ **Roy H. Heald** (AF) of the National Bureau of Standards Fluid Mechanics Section, Mechanics Division, has been awarded the Department of Commerce Silver Medal for Meritorious Service for "... long and distinguished service in the field of missile aerodynamics."

Members on the move . . . .

This section provides information concerning the latest affiliations of IAS members. All members are urged to notify the News Editor of changes as soon as they occur.

Harry M. Baldwin (A) has joined United Aircraft Corporation, Pratt & Whitney Aircraft Division, Florida, as General Foreman, Quality Control. He had held the same position in the Lycoming Division, Avco Manufacturing Corporation.

Eugene L. Brickman (M), who was a Design Engineer at Anderson, Greenwood & Co., is now a Senior Test Engineer at Chance Vought Aircraft, Inc., Dallas, Tex.

Monroe R. Brown (M), Engineering Personnel Administrator, Wright Aeronautical Division, Curtiss-Wright Corporation, has been promoted to full Colonel in the Air Force Reserve.

Robert V. Brulle (M), formerly an Air Force Captain and Associate Professor of Aeronautical Engineering, Air Force Institute of Technology, Wright-Patterson AFB, has joined McDonnell Aircraft Corporation as Senior Engineer, Missile Aerodynamics.

Charles E. Burns (M) has been named Manager, Aircraft and Missiles Department, Project Development Division, The Ralph M. Parsons Company. He had been Military Sales Representative, Lockheed Aircraft Corporation.

John B. Clark (A), Assistant Chief, Environmental Protection Branch, ARDC Aeronautics Division, has been promoted to the rank of 1st Lieutenant at the Air Force's ARDC Headquarters.

Joseph H. Clarke (M), formerly Assistant Professor of Aeronautical Engineering, Polytechnic Institute of Brooklyn, has joined Brown University as Associate Professor, Division of Engineering.

Clarence B. Cohen (AF) has joined the Guided Missile Research Division, The Ramo-Wooldridge Corporation. Dr. Cohen had been Associate Chief, Special Projects Branch, Supersonic Development Division, NACA, Cleveland, Ohio.

Lt. Gen. Laurence C. Craigie, USAF (Ret.), an IAS Vice-President and Associate Fellow, has been elected to the Board of Directors of Associated Missile Products Corporation, Pomona, Calif., a subsidiary of American Machine & Foundry Company.

Craig H. Edwards (M), who was Manager, West Coast Sales and Service, New York Airbrake Company, has joined The Weatherhead Company as West Coast Sales Manager for aircraft and ordnance.

Lester J. Henderson (A), formerly General Sales Manager, Special Products Division, The Weatherhead Company, has joined Republic Manufacturing Company as Vice-President in charge of Sales.

Richard E. Horner (M), former Technical Director of the Air Force Flight Test Center, Edwards AFB, has been nominated by President Eisenhower to be an Assistant Secretary of the Air Force.

Comdr. Harry J. Huester (M), has been transferred from Jacksonville Naval Air Station, Aeronautical Engineering Department to the Naval Air Material Center, Philadelphia Navy Yard.

Thomas J. King, Jr. (A), formerly an Aeronautical Research Scientist, NACA, Langley, has joined Temco Aircraft Corporation as Senior Engineer in Aerodynamics.

Nelson Kling (M), formerly Chief Engineer, Arkwin Industries, Inc., has joined Eastern Aircraft Products Corporation, a subsidiary of Weatherhead Company, as Chief Design Engineer.

Lloyd G. Ludwig (M) has left Douglas Aircraft Company, Inc., to join the Guided Missile Division, The Ramo-Wooldridge Corporation. He had been a Research Engineer at Douglas.

Donald H. McClelland (A), Aeronautical Engineer, has joined the Guided Missile Research Division, The Ramo-Wooldridge Corporation, Los Angeles, Calif.

Charles W. Miller (M), who was a Preliminary Design Engineer at Northrop Aircraft, Inc., has joined the Guided Missile Research Division, The Ramo-Wooldridge Corporation, Los Angeles, Calif.

J. O. Montanaro (M), has left his position as Senior Technical Officer, National Aeronautical Establishment, Ottawa, to join the Kaman Aircraft Corporation, as Staff Engineer.

Michael K. Rastiello (A), former Aerodynamics Specialist, Consultants and Designers, Inc., is an Aerodynamics Engineer with North American Aviation, Inc., Columbus Division.

Richard W. Sanford (M), Chairman of the IAS Baltimore Section and previously Chief Engineer and Director of Engineering, Aircraft Armaments, Inc., has been elevated to Vice-President and Director of Engineering for his firm.

(*Continued on page 78*)

Necrology

Emerson C. Briggs

Word of the death of Emerson C. Briggs (M), on May 8, has reached the Institute. Mr. Briggs, 43, was a Stress Analyst for Kaman Aircraft Corporation.

Born in Albion, N.Y., he obtained a degree in Aeronautical Engineering from the University of Minnesota in 1939. In November of that year he joined the Glenn L. Martin Company as an Inspector of major assemblies. He also was a Junior Stress Analyst for Bell Aircraft Corporation, which he joined in May, 1941.

Later in 1941 he became Project Weights Engineer for Bell, working on the XP-77 until 1945 when he held the same position in connection with the Model 47 helicopter.

Mr. Briggs joined Kaman in 1951 as Senior Stress Analyst. Besides his membership in the IAS, he also was a member of the American Helicopter Society.

John A. Eubank

The Institute mourns the loss of John A. Eubank (M), an attorney who had spent some 25 years in close association with aeronautical jurisprudence before his death in Jamaica, Long Island, on June 18.

He was born in Baltimore and educated at St. Lawrence University and Brooklyn Law School where he was Professor of Aeronautical Law for 16 years.

Mr. Eubank was a recognized authority on aeronautical law and conducted three national symposiums on it in 1933, 1938, and 1946. He received the Aeronautical Progress Award for his work.

He had served as Chairman of the Committee on Aeronautical Law of the Federal Bar Association of New York, New Jersey, and Connecticut. He was a former governor of the Aircraft Industries Association; a member of the National Aeronautic Association and the Soaring Society of America; and had been an Historical Associate Fellow of the IAS. Mr. Eubank also was the author of a three-volume work, *Aeronautical Jurisprudence*.

He was the author of resolutions "Reaffirming the Doctrine of Sovereignty in Airspace" and the "Principle That the Use of the Airspace in International Air Navigation Must Be Based on International Agreement."

Lt. Almos E. Land

The Institute has received news of the death of Lt. Almos E. Land (A), USAF, in an aircraft crash in Japan on May 8. Lieutenant Land was 25.

A native of Clewiston, Fla., he entered the Air Force in 1955. Prior to his military service, he was an Associate Engineer, Flight Test Design, for Lockheed Aircraft Corporation's Georgia Division.

Lieutenant Land was an aeronautical engineering graduate of the Univeristy of Florida.

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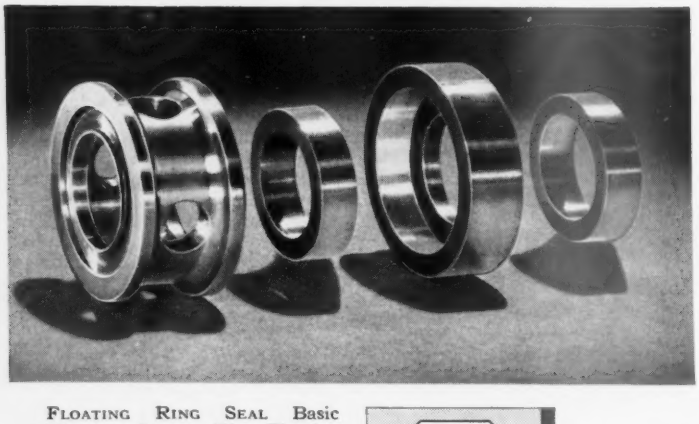
Seal Any Medium—Even Corrosive Media ... with Koppers Floating Ring Seal

MULTIPLE RING TYPE Floating Ring Seal (assembled)



FLOATING RING SEAL Basic Elements: Lantern Ring, Floating Ring, and Spacer Diaphragm. As sealing needs dictate, floating rings and spacer diaphragms are added. Seals are carbon, plastics, ceramics or steel, as applications require.

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It seals at high temperatures and at pressures up to, and for some conditions even above, 2000 psi. Inspection has shown that after 10,000 hours of operation, ring and spindle wear can be negligible. For water at 500° F. and 1200 psig with a $\frac{5}{8}$" spindle, leakage is only one to two pounds per hour. Frictional power requirements are virtually zero, and Koppers' design reduces radial frictional restraint. Sealing members adapt to changes in the shaft's position.

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PROFESSIONAL NOTES AND REPORTS

Engineering and Scientific Briefs from Correspondents Around the Globe

New Melt Method Defeats AL-13 Susceptibility to Gases

◆ "Treating AL-13 Alloy With Potassium Zirconium Fluoride and a Stream of Nitrogen," a 1955 Soviet paper by L. O. Sokolovskiy and A. G. Kapalin, describes a new melting method to overcome the susceptibility of AL-13 to high gas contents, especially hydrogen. The authors state that AL-13 castings are used in machinery plants because of their high resistance to corrosion combined with the simple processing required. The new melting method involves use of an already-allowed charge, rapid melting, optimum melting and pouring temperatures, suitable treatment with a molten K_2ZrF_6 flux, and a stream of nitrogen. With the use of this method, costs were about 10 to 15 per cent higher than with the previous practice, but sounder castings with higher strengths and ductilities were obtained.

The evidence would indicate that the former foundry practice was not suitable for this grade. The properties obtained with the new melting method are similar to normal expectancy for the equivalent U.S.A. grade (B 214).

It is agreed that this grade has a strong tendency to absorb hydrogen, as well as to form oxides and dross. Careful melting practice and especially proper temperature control are, therefore, needed to obtain satisfactory castings. Various fluxes are used for treating the molten metal; among the most common are chlorine gas, nitrogen gas, various chlorides, and proprietary compositions. The experts, however, all stress that a flux is not always necessary when proper melting practices are used. Hence, when a flux is used, it should be considered as a supplement to good melting and handling practices and not as an agent to offset the effects of otherwise inferior foundry techniques.

U.S.S.R. Book on Cosmic Rays Seen of Interest to 10,000

◆ A book on cosmic rays—intended for physicists who are not specialists in the subject, postgraduate students, and students in physics departments—was recently published in the U.S.S.R. The book is written by N. A. Dobrotin and covers only the most essential problems in the field without going into detail concerning experimental arrangements. However, it presents a fairly complete picture of the phenomenon of the passage of high-energy particles through matter, including electron-nuclear showers and nuclear-cascade processes.

Cosmic-ray physics is one of the most rapidly developing branches of modern science. Many of the discoveries of new particles, such as the positron and various mesons, were first made in cosmic-ray experiments. It is in the cosmic rays that high energies (up to one billion volts) are supplied by nature. Man-made energies of this order can be produced only by large accelerators and at enormous expense.

For a number of years the Soviets have spent considerable time in fundamental research work in the field of cosmic rays. It is in keeping with the philosophy of the Soviets to spend a considerable amount of their effort in basic research. Furthermore, experiments with high-energy particles provide one approach to a knowledge of the nucleus.

One of the significant things about the book is the fact that this edition called for 10,000 copies. This might be considered an indication of the number of persons in the U.S.S.R. who are at a sufficiently high level to read the book and have an interest in it.

Superior CO_2 Absorption Claimed for India Material

◆ A material which absorbs carbon dioxide rapidly and efficiently has been developed by the Fuel Research Institute, Jealgora, India. According to the inventors, the material, called Lisasorb, has practical application in the design of respirator devices for protection against toxic gases or for use in atmospheres not suitable for humans because of oxygen shortage. It also is recommended for closed breathing systems which have oxygen available and in which the carbon dioxide produced must be absorbed.

Lisasorb consists essentially of fixing soda lime on a kieselguhr-alumina (infusorial earth and aluminum oxide) base under defined and controlled conditions. The main materials required are burned lime, caustic soda, and kieselguhr. The material has low resistance to airflow, low temperature rise due to absorption, and does not readily disintegrate or agglomerate. It also has little alkali or other materials which may affect the rubber in gas mask assemblies. Lisasorb was far superior to the standard imported absorbents tested at the Fuel Research Institute.

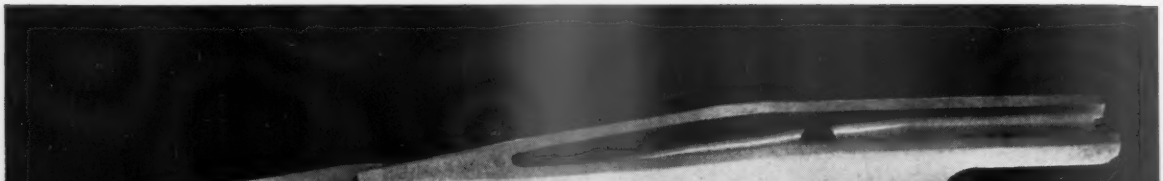
Carbon-dioxide absorption materials are probably more practical in closed ventilation systems such as in mines, interiors of large buildings, or pressurized compartments (aircraft cockpits) than in open areas. However, gas masks would undoubtedly afford greater protection and increased breathing efficiency if this principle of absorption were incorporated in their structure. Further, leakage in gas masks around outlet valves would be eliminated.

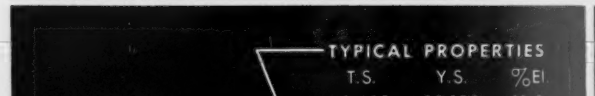
Cutting Tool Ceramic Tips Soldered by Soviet Process

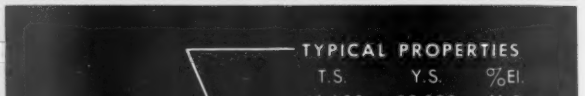
◆ According to a recent article in the Soviet magazine, *Tekhnika-Molodezhi*, the U.S.S.R. has devised a method for soldering ceramic tips to the metal shanks of cutting tools. The article states that the Soviets have built a special vacuum unit in which the tips can be metallized. A paste containing titanium is placed on the tool and covered with thin copper foil. The tip is then clamped to the tool, placed in a drip pan, and loaded into the vacuum unit in which a vacuum of 0.01 mm. of mercury is created. (The vacuum is necessary to prevent the oxidation of the copper.) The foil melts at a temperature of 1,150° to 1,180° and spreads out over the surface of the tip and into its pores. The Soviets claim that the titanium facilitates the penetration of the copper into the ceramic. They also claim that the tips soldered in this manner are three to four times as strong as tips fastened by other methods and that the tips can be ground seven or eight times or until the tip is almost completely used up.

If this process is satisfactory, the Soviets have solved one of the major difficulties in the preparation of ceramic tools. Ceramic tips used at the present time are held by mechanical fasteners (which are unsuitable and clumsy) because there is no known method for soldering or cementing them to the metal shanks.

HIGH-STRENGTH ALUMINUM CASTINGS







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Growth of Versatile AN-2 Discussed by O. K. Antonov

◆ An article in a recent British publication reported on an interview with Soviet aircraft designer O. K. Antonov. During the interview Antonov discussed the development of the AN-2. He said that the first model, designated the SKh-1, was intended for purely agricultural use and made its first flight in 1947. The prototype was powered by a 630-hp. ASh-21 engine, and the early production models were powered by this engine or by the 1,000-hp. ASh-62 IR. Antonov said that the SKh-1 was highly successful and that, now known as the AN-2, it is used for a wide variety of jobs in addition to agricultural use.

Mass production of the AN-2 was undertaken at Kiev, where several versions have been built. One of these is the AN-2ZA (which, he said, bears the design bureau designation AN-4) originally intended for high-altitude meteorological work. Antonov claimed that this variant established a world altitude record for its class in 1954 by attaining 36,903 ft. He described the AN-2V (design bureau designation AN-6) as a twin-float seaplane version and said that it is in large-scale production. Antonov said that the latest version is an artillery spotter with twin fin-and-rudder and a single-gun tail turret.

Photographs of an AN-2 with a canopy just ahead of the tail and a turbosupercharger have been seen. It is presumed that this variant is the AN-2ZA.

Soviet Oxygen Mask Good for 2 Hours Maximum Operation

◆ The Soviet KIP-5 oxygen mask is a closed breathing system designed for protection against chemical agents capable of penetrating filtration-type mask assemblies. The complete system weighs less than 20 lbs.

Components of the system include an oxygen tank for compressed oxygen, a regenerative cartridge which removes carbon dioxide from exhaled air, and a breathing bag in which oxygen is mixed with the exhaled air. The basic parts of the mask assembly include a facepiece with inlet and outlet connecting hoses, a safety valve on the breathing bag, a lower connecting case, an oxygen-supply regulator, and the assembly housing.

The regenerator cartridge will last for 2 hours of continuous operation, and the oxygen supply is sufficient for 45 to 60 min. However, the oxygen tank can be exchanged during operation, whereas the regenerator cartridge cannot.

The oxygen regulator can be set for predetermined pressure settings for supplying oxygen to the bag. An automatic compensating device will permit an increased amount of oxygen to the bag if more is needed by the wearer. This device is activated by deeper breathing.

Although this mask is too expensive and too complicated for use by all ground forces, it would certainly be used by the chemical decontamination squads and CW detection units.

Sweden's J-35 Dragon Being Produced in Quantity

◆ The SAAB Aircraft Company has announced officially that the J-35 is in quantity production "with deliveries to the Air Force scheduled within the next few years."

During a recent demonstration, the Dragon made several low-altitude, high-speed runs and showed "considerable supersonic speed" in level flight at about 23,000 ft.

All-up weight of the Dragon is 8–9 tons, depending upon armament.

Antonov "Leading Designer" of New Soviet Turboprop Liner

◆ The March 9, 1957, issue of a Soviet aviation magazine contained an article entitled "The Aircraft 'Ukraine' in the Air."

The article stated that Ukraine is the name of the new Soviet passenger turboprop aircraft and that "the other day it started on the first flight test." Further, it stated that Nikolai Stepanovich Trunchenkov, of the O. K. Antonov design bureau, was the "leading designer" of the new aircraft.

In closing the article stated:

"First of all, it surprises us with the dimensions of the wide and rather spacious, all-metal fuselage over which are stretched long narrow wings. On these are four turboprop engines. In spite of their great horsepower, the engines appear to be miniature and compact. They operate on low-grade fuel and consume by far less than turbojets. From Kiev to Moscow it takes one hour of flight. The aircraft has a relatively low landing speed. It can take-off and make a landing on ordinary soil aerodromes."

Antonov has stated publicly that his bureau was engaged in the design of a new transport powered by four turboprop engines. Also, an aircraft bearing the name Ukraine on the side, and credited to Antonov, was shown in a photograph released by *Pravda*. The photograph revealed that the fuselage was quite large, and the caption indicated the cruise speed as about 325 knots. Inasmuch as the distance between Kiev and Moscow is about 400 nautical miles, a normal flight should take longer than the 1 hour (even considering wind effect) stated in the magazine, or—if not—the cruise speed is higher than the 325 knots reported, a fact which is considered doubtful.

New Fuels, Jet Progress Debated by Soviet Designer

◆ Professor V. M. Myasishchev, a Soviet aircraft designer of some note, recently wrote an article entited "Leaving Time Behind," in which he has attempted to encompass the progress that has been made and that eventually will be made in the development of air frames, engines, and fuels in the U.S.S.R. The article is flavored with a few statements on the feasibility of space flight and also the estimated time period in which man will conquer space.

The improvements made in jet engines appear to be of major importance in the article, and specific examples of present and future engines are given. Convertiplane and VTO applications are mentioned in conjunction with the engines to give a more vivid example of the high thrust-to-weight ratios attained when jet engines are utilized. The author mentions the possibility of supersonic speeds with this type of aircraft.

Reduction of the weight and volume of aircraft fuel by increasing its heat-producing capacity is also an important part of the article. Introduction of powdered aluminum, magnesium, or other metals into conventional fuel (slurries) is one method of increasing the heat-producing ability of the fuel. Another trend in the evolution of high-heat fuels is the development of the boron-hydrazene compound pentaborane. Because of its high rate of combustion, pentaborane makes it possible to reduce the length of the combustion chambers and thus reduce the engine size, according to the author. Professor Myasishchev states, "The design of engines operating on higher energy fuel appears to be the transition link from modern aircraft to those utilizing nuclear fuel."

Professor Myasishchev states also that the introduction of little known metals in aircraft (titanium, tantalum, molybdenum, niobium) is necessary due to the increasing temperatures and stresses encountered in high-speed flight. Because of these extreme conditions, "scientists of all countries work persistently to create new heat-resistant alloys capable of meeting the requirements of jet aviation."

NEXT MONTH

The September issue of the Review will include the IAS Roster of Members. It will also commemorate the Institute's Twenty-Fifth Anniversary.

Sir George Edwards

President, The Royal Aeronautical Society
Managing Director, Vickers-Armstrongs (Aircraft) Ltd.

Mundy I. Peale

President
Institute of the Aeronautical Sciences

President
Republic Aviation Corporation

EDITORIAL

SIXTH ANGLO-AMERICAN CONFERENCE

Before the next issue of the *Review* comes off the presses, over 100 delegates of the Institute (accompanied by wives and children, a total of over 140 for the entire party) will be on the way to England by land, sea, and air for the Sixth Anglo-American Conference (RAeS-IAS). For many of the group, the score will be "six-out-of-six." A surprising number has made all previous Conferences—London, 1947; New York, 1949; Brighton, 1951; London, 1953; and Los Angeles, 1955. Out of these exchanges have come many lasting personal and professional contacts. The Sixth will be no exception.

It is of interest to note that the present heads of both the leading technical and scientific societies of the English-speaking nations are outstanding aeronautical industrialists. They have much in common. Each is young, dynamic, and at the peak of his career. Each heads one of the largest and most successful aircraft manufacturing concerns in his own country. Obviously they are both very busy men.

And yet, both Sir George Edwards and Mundy Peale are devoting a large amount of interest and energy to their respective scientific societies. It is certainly not for *kudos*—each has attained enough of such intangibles, and to spare. Their interest stems rather from their own engineering and technical backgrounds. They both came up via the technical side of aviation.

They are each aware of the staggering scientific and engineering requirements of this fast-moving aircraft and missile business, and they recognize the great contributions that are being made by our two scientific societies toward meeting those requirements. It is to help direct the capabilities of the two Societies in promoting the interchange of essential information among engineers and scientists of our two countries that they are willing to devote time from their busy lives to the problems of the RAeS and the Institute. We are fortunate indeed that this recognition exists and that men of the caliber of Edwards and Peale lead the two delegations to the Sixth Conference.

For those who have attended other Conferences, we have no need to speak. You will be going back to meet old friends in an atmosphere of relaxed friendship. To those attending your first Conference we can assure you that you will enjoy it and will find it most profitable. Our "opposite numbers" in Britain pride themselves on their hospitality, and all arrangements are in good order for the comfort and convenience of our delegates. One word of caution. The planned program is a full one, and its successful operation depends on the cooperation of all concerned. If your plans as a delegate change in any way, please be sure to contact the Royal Aeronautical Society (4 Hamilton Place, London, W. 1) immediately so that necessary arrangements can be made promptly.

S.P.J.

Through better integration of complex requirements into a consistent system have come the modern solid-propellant rockets, equipped to withstand the severe environmental conditions to which they are subjected.

Modern Developments in Solid-Propellant Rocket Engineering

Richard D. Geckler* and Robert E. Davis**
Aerojet-General Corporation

Introduction

The trend in rocket development today is toward larger and more efficient rockets, brought on by the need for increased size or performance of missiles. In addition, the operational requirements imposed on rocket power plants have become increasingly stringent. Consequently, the development of larger and more efficient rockets is accompanied by a need to withstand more severe environmental conditions in the field.

The question arises as to why solid-propellant rockets should be seriously considered since many combinations of liquid propellants are available for use in rocket power plants. After many disappointing trials with solid-propellant rockets, the early amateur rocket enthusiasts unanimously concluded that progress toward their goal of space flight would come about only if they switched to liquid propellants. For example, Willy Ley comments that "even the most ordinary of liquid fuels, ordinary automotive gasoline, will produce an exhaust velocity about twice that of a black powder rocket."[1] This type of conclusion biased the direction of rocket development work for more than a score of years. However, it overlooked the fact that new solid propellants far superior to black powder would be invented and tailored specifically to meet rocket requirements or that the principles of rocket design could be refined as they subsequently were. Today there are impressive reasons for considering solid-propellant rockets for many applications.

Two important reasons are the inherent simplicity and reliability of solid-propellant rocket motors. This simplicity exists not only in construction details, because there are fewer parts than in liquid rockets by a factor of 100 to 1,000, but also in field use. Servicing of the rockets with propellants on the launching platform is unnecessary. There are no pumps, valves, or controls to get out of order. To start a solid-propellant rocket it is only necessary to insert the igniter and press the firing switch.

Hand in hand with simplicity goes reliability. For example, the reliability of all solid-propellant rockets delivered by the Aerojet-General Corporation during its history is about 99 per cent. However, this figure is an average including older and less reliable models as well as newer and more reliable ones. One of the newer Aerojet-General solid-propellant rockets has an actual measured reliability of 99.99 per cent and this is after being subjected to extreme environmental conditions.

Along with simplicity and reliability goes another factor that seems to be less widely appreciated—this is reduced cost. Both the cost of development and the cost of production are generally less for solid-propellant rockets than for equivalent liquid-propellant rockets. The reduced costs are a direct result of the simplicity of the rocket in that fewer component parts must be developed.

Nevertheless, there are some disadvantages of solid propellants. The performance of solid-propellant rockets has been less than for liquid-propellant rockets—in regard to the energy content of the propellant as measured by the specific impulse and often in regard to metal parts weight. Another drawback of solid-propellant rockets that in the past hindered their use in some applications is the difficulty of varying the thrust. The direction and magnitude of the thrust of a liquid-propellant rocket can be controlled by gimballing the thrust chamber and by throttling the propellant flow. Thrust can be terminated simply by closing the propellant valves.

However, recent developments in achievement of solid propellants of higher specific impulse and in metal parts of light weight, as well as successful tests of

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methods for controlling thrust, have broadened the range of applicability of solid propellants.

Some developments in improving the design of solid-propellant rockets, both by increasing the propellant specific impulse and by increasing the propellant mass fraction, will be discussed. Environmental testing, especially temperature-cycling, of solid-propellant rockets will be considered as applied to propellant grain design.

Discussion

Since the altitude of a sounding rocket or the range of a rocket missile depends primarily on the burnout velocity, the problem of maximizing rocket performance in general is equivalent to the problem of maximizing the burnout velocity. To a first approximation the burnout velocity of a rocket-powered vehicle is given by the ideal rocket velocity equation

$$v_b = c \ln R \tag{1}$$

where v_b (ft.sec.$^{-1}$) is the velocity reached by the vehicle at the end of propellant burning in gravity- and drag-free space after starting from rest; c (ft. sec.$^{-1}$) is the effective exhaust velocity of the propellant related to the specific impulse I_s(lbf.sec.lbm^{-1}) by the equation

$$c = g_c I_s \tag{2}$$

where $g_c = 32.174$ lbm.lbf^{-1}ft.sec.$^{-2}$, and R is the ratio of the mass of the vehicle at the beginning of burning, M (lbm), to the mass of the vehicle at the end of burning, M_b(lbm). If M_p(lbm) is the mass of the propellant discharged during burning, the power-plant mass fraction of propellant is defined by

$$\Lambda = M_p / M_r \tag{3}$$

where M_r(lbm) is the total mass of the rocket power plant including propellant. Further, the overall pay-load mass ratio α can be defined by

$$\alpha = M / M_l \tag{4}$$

where M_l(lbm) is the mass of the pay load accelerated by the rocket power plant. The total vehicle mass is the sum of the pay-load mass and power-plant mass

$$M = M_l + M_r = M_l + M_p + M_c \tag{5}$$

where M_c(lbm) is the combustion chamber mass which should include any ineffective propellant such as slivers. In addition, it is seen that the ratio of mass of the power plant to the pay-load mass is given by

$$M_r / M_l = \alpha - 1 \tag{6}$$

Using the above equations, a plot has been constructed of the overall pay-load mass ratio α versus the power-plant propellant mass fraction Λ for various values of v_b/c, the ratio of vehicle burnout velocity to effective exhaust velocity of the propellant as shown in Fig. 1. It can be seen from Eq. (1) that vehicle burnout velocity can be increased either by increasing the propellant specific impulse I_s and hence the effective exhaust velocity c or by increasing the ratio of vehicle weight at the beginning of burning to the vehicle weight at the end of burning R. However, the latter ratio depends both on the size of the power plant relative to the pay load and on the propellant fraction of the power plant. A study of Fig. 1 shows that for a given vehicle and propellant performance—i.e., constant value of v_b/c—there is a minimum pay-load mass ratio necessary no matter how high the propellant weight fraction in the power plant becomes. There is also for constant v_b/c a minimum propellant weight fraction required no matter how high the ratio of total vehicle mass to pay-load mass is made. Thus it can be concluded that future requirements for increased vehicle performance—i.e., larger values of v_b—will necessitate increasing the propellant specific impulse, the development of larger rocket power plants, and increasing the propellant fraction of the rocket power plants.

Maximum Propellant Specific Impulse

The specific impulse of a rocket propellant depends chiefly on the energy released by the propellant as it burns and, to a lesser degree, on the operating pressure of the rocket and the expansion ratio of the nozzle. The potential energy of the propellant available for release when the propellant burns is a function of the chemical composition of the propellant. Solid propellants are of two general types: double base and composite. Double base propellants consist essentially of nitrocellulose colloided with nitroglycerin. Composite propellants consist basically of an oxidizer mixed with a combustible binder, and, except for exotic propellants still in the laboratory stage, the oxidizer is a simple inorganic salt containing oxygen. Potassium perchlorate, ammonium perchlorate, and ammonium nitrate are the oxidizers in general use. Many varieties of binder have been utilized in solid propellants, but in general the binder serves chiefly as a fuel, although it usually contains some available oxygen. For a given oxidizer and binder system, the problem of achieving the highest possible specific impulse becomes a problem of obtaining a high ratio of oxidizer to binder. However, there are limitations on the amount of oxidizer that can be placed in a given binder, and then the specific impulse obtainable

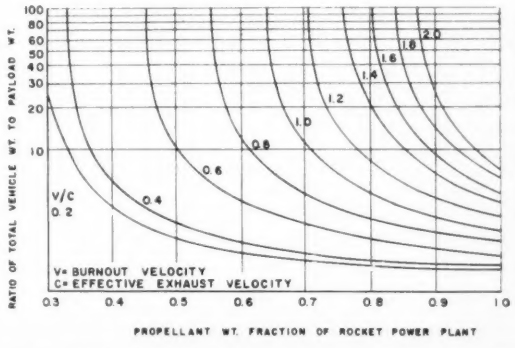

Fig. 1. Total vehicle to pay-load weight ratio vs. propellant fraction of rocket power plant for various burnout velocities.

from the propellant system is less than the theoretical maximum. If the propellant is of the castable type, the oxidizer content in the oxidizer-binder slurry cannot be so high that the slurry will not flow into a mold or rocket case preparatory to curing of the slurry to a solid. Some benefit in castability can be realized by adjusting the particle size of the oxidizer, but even with an optimum oxidizer particle size distribution for castability there is a limit to the oxidizer loading that will permit the slurry to flow. The maximum oxidizer loading is also limited to a certain extent by its effect on the mechanical properties of the propellant, especially elongation under tension, and in some propellant systems by increased susceptibility to detonation as the oxidizer content of the propellant is increased. Many propellants are now available with values of specific impulse well over 200 blf.sec.lbm^{-1}, compared to black powder for which $I_s = 70$ blf.sec.lbm^{-1}, and it does not appear that any theoretical limit to even higher values has yet been reached.

The specific impulse available from a solid propellant can be increased by operating a rocket at increased chamber pressure since the performance of a rocket nozzle is a function of the ratio of the chamber pressure to the atmospheric pressure. The thrust developed by a rocket can be expressed as

$$F = C_F A_t p_c \tag{7}$$

where F is the thrust, C_F is the thrust coefficient, A_t is the nozzle throat area (in.^{2}), and p_c is the chamber pressure (lbf.in.$^{-2}$). The thrust coefficient C_F is a function of the ratio of chamber pressure to exit pressure, the expansion ratio of the nozzle (ratio of nozzle exit area to throat area), and the ratio of specific heats of the propellant gases. Fig. 2 illustrates the variation of C_F with pressure ratio and expansion ratio for propellant gases with a specific heat ratio of 1.20. It would appear that operation at very high values of the chamber pressure would be advantageous. However, the chamber pressure is limited by the strength of the rocket case, and operation at too high a chamber pressure will require such a strong and therefore heavy rocket case that the overall efficiency of the rocket will be decreased because of its high weight. One of the basic advances in rocket design has been, therefore, to choose the chamber pressure which will maximize the rocket burnout velocity.

For a given propellant and a given ratio of chamber pressure to atmospheric pressure, there is an optimum ratio of nozzle exit diameter to throat diameter for a nozzle to have maximum efficiency and, hence, utilize the available energy of the propellant to the fullest. Values of the thrust coefficient at optimum expansion lie on the dotted line in Fig. 2. During flight of a missile or sounding rocket where the altitude and the outside pressure are changing, the chamber pressure to exit pressure ratio and hence the optimum expansion ratio will change. The nozzle will then be at optimum expansion only at the altitude for which it is designed, and therefore the propellant specific impulse will be at a maximum only at that altitude. Consequently, some compromise in rocket performance is necessary. For example, consider a rocket operating at 1,000 psi chamber and optimum expansion at sea level. The pressure ratio will then be 1,000/14.696 = 68.2, and, referring to Fig. 2, the area ratio for optimum expansion is 9.4, and the thrust coefficient is 1.57. At 100,000 ft. altitude, the pressure ratio is 1,000/0.158 = 6,320, and the thrust coefficient for an area ratio of 9.4 is 1.78, which shows that the thrust of the rocket increases with altitude. However, optimum expansion would give a thrust coefficient of 1.93, but the nozzle expansion ratio would have to be increased from 9.4 to 430. Obviously proper choice of the nozzle area ratio is of considerable importance in achieving the maximum performance of a vehicle traversing the atmosphere.

Maximum Weight Fraction of Propellant

For a rocket and pay load of given weight, the burnout velocity can be increased not only by increasing the propellant specific impulse but also by increasing the weight fraction of the propellant in the rocket power plant. With a propellant grain of fixed dimensions the propellant weight can be maximized by using a high density propellant. For this reason it is sometimes advantageous to employ a propellant of lower specific impulse but high density rather than a propellant of higher specific impulse but low density. The optimum compromise for maximum performance can be established only by detailed calculations based upon Eqs. (1) and (7).

Considerable freedom in design of the propellant grain configuration is available as a means of obtaining the maximum weight fraction of propellant in the rocket. Assuming a rocket chamber of fixed diameter and length and end closures of fixed dimensions, the volume surrounded by the chamber and end closures will be occupied by propellant, insulation, grain supports, igniter, and volume available for flow of propellant gases. The volumes occupied by the various components in a typical rocket might be as follows:

	% of Total Volume
Propellant Grain	75.7
Insulation	
Chamber Barrel	1.3
Fore and Aft Heads	0.2
Grain Supports	0.6
Igniter	0.4
Volume Available for Gas Flow	21.8
Total	100.0

The volume occupied by the igniter will be small and therefore has little effect on the maximum weight fraction of propellant obtainable. The insulation required to keep the fore and aft closures from overheating, the chamber barrel insulation, and the grain supports generally do not offer much leeway in design of the rocket for maximum propellant loading. Therefore, the main effort of the rocket design engineer in obtaining maxi-

mum volumetric propellant loading is directed toward reducing the volume of gas flow.

An unperforated cigarette-burning grain will give the greatest loading density, but this type of configuration may require a higher propellant burning rate than available. In such cases a perforated grain must be used, and the minimum free space in the chamber available for flow of propellant gases is often determined by the magnitude of "erosive" burning that occurs when the normal burning rate of a solid propellant is increased by flow of gas parallel to the burning surface. The higher burning rate causes an increase in the chamber pressure, and hence, excessive erosive burning causes a pressure peak at the start of firing when the port area available for gas flow is low and the velocity of gas past the burning surface is high. The minimum free volume in the chamber is thus limited by the port area necessary to avoid excessive erosive burning. Design of the propellant grain to achieve the maximum propellant loading must take this fact into account.

Proper design of the metal parts of a rocket for minimum weight will also help to increase the weight fraction of propellant. In fact, it is here that the greate t opportunity probably exists for improvement in the weight fraction of propellant and achievement of higher vehicle burnout velocities. Considerable study has been given to methods of decreasing the weight of pressure vessels, and the results of some of these studies are available in the classified literature. Rocket chambers can be fabricated of alloy steels heat-treated to high ultimate strength to permit thinner walls and hence lower weight. Investigation of other structural materials with promise of higher strength-to-weight ratios than steel are underway. Minimum weight for insulators and grain supports are also desired, and use of a case-bonded propellant grain can contribute to decreasing the weight of these components.

The weight of the rocket nozzle is usually an appreciable part of the total metal parts weight for a solid-propellant rocket, and good nozzle design can result in substantial saving of weight. Much less work has been done on the design of minimum weight no zles than has been expended in designing lightweight chambers, and as a consequence rocket nozzles are in general overdesigned. Determination of the wall thickness necessary at each section along a rocket nozzle is more complicated than, for example, calculation of wall thickness for a cylindrical chamber barrel. As the propellant gases expand through the nozzle, the static pressure exerted by the gases decreases, and hence the thickness of nozzle wall necessary to withstand this pressure decreases. The heat-transfer coefficient between the gases and the nozzle is also decreasing as the gases expand thus requiring less insulation of the nozzle wall to protect against overheating. It appears that much can be done in designing lighter weight nozzles by varying the nozzle wall thickness and thickness of insulation materials; judicious selection of materials that can serve as combination erosion barriers, insulators, and structural members; and use of other than conical exit sections. Use of different shapes for the exit section has been limited by fabrication difficulties and a study of improved fabrication methods seems warranted.

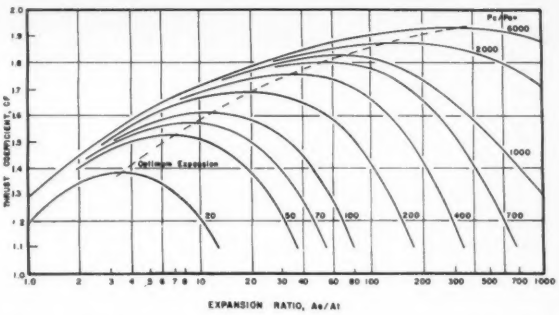

FIG. 2. Thrust coefficient vs. expansion ratio. Theoretical values for $k = 1.20$, $\lambda = 0.9830$ (for $\alpha = 15°$).

Environmental Conditions

In addition to designing a rocket motor for optimum ballistic performance, the rocket designer must consider the environmental conditions to which the rocket will be subjected. The most severe environmental requirement is usually the broad temperature range over which the rocket must operate. The propellant must withstand the stresses imposed by changing temperature without cracking and the rocket must also fire successfully at all temperatures within the specified range.

To permit successful firing of a solid propellant rocket, various design criteria must be fulfilled. First, the propellant must ignite properly at all temperatures, and this is a problem for some propellants that are not readily ignitible at low temperatures. Then, the operating pressure at high temperatures produced by burning of the propellant must be below the design strength of the rocket chamber. This requires that the chamber design take into account the temperature sensitivity of the propellant. The propellant burning rate and therefore the rocket chamber pressure will in general increase with temperature. Let us assume that a certain rocket operates at 1,000 psi pressure at 60°F. and employs a propellant with a temperature sensitivity of pressure equal to $0.0020°\text{F.}^{-1}$. That is,

$$\pi_p = (1/p)(\partial p/\partial T)_K = 0.0020°\text{F.}^{-1} \qquad (8)$$

The subscript K denotes that the ratio of the nozzle throat area to burning area is held constant. To calculate the burning rate and pressure at 160°F. the following equation is used:

$$p_{160°}/p_{60°} = \exp \pi_p(160 - 60) \qquad (9)$$

The operating pressure is thus 1,222 psi at 160°F. compared to a value of 1,000 psi at 60°F. In this example, it is apparent that the temperature sensitivity of the propellant requires the design pressure to be 20 per cent greater than it would be otherwise. As a consequence much work is being done to reduce the temperature sensitivities of solid propellants.

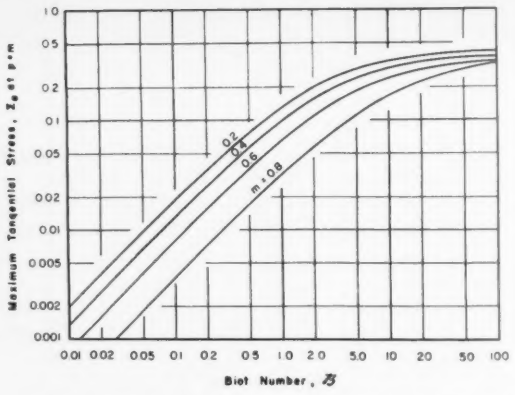

FIG. 3. Maximum tangential thermal stresses at the inner surface of a hollow cylinder vs. Biot Number (E independent of temperature).

A more important effect of the thermal environment on a rocket is the thermal stress produced in the propellant by temperature cycling. Especially interesting is the comparison of thermal stresses in a free-standing and case-bonded grain. Let us assume that in the two rockets, one with a free-standing and one with a case-bonded grain, the grains are in the stress-free condition at a temperature of 100°F. The rockets are then suddenly subjected to a temperature of −40°F. and remain in that temperature environment for a long time. Thermal stresses will be induced in the free-standing grain and these stresses will reach a maximum after a certain time and then decline to zero. At equilibrium the grain will again be stress-free. However, in the case-bonded grain, thermal stresses will be induced and will remain in the grain even at infinite time because the grain is restrained by the chamber as it tries to shrink away.

These effects can be illustrated as follows: Consider the free-standing grain to be an infinitely long hollow circular cylinder of external radius R_e, internal radius R_i, and initially at the temperature T_i. At time $t = 0$, heat is transferred to the external cylindrical surface of the grain from a medium at temperature T_g with a constant heat-transfer coefficient h; there is zero heat flux at the internal surface. The heat-transfer coefficient h is the overall coefficient considering transfer of heat from the surroundings through the chamber insulation, if any, and air space to the propellant grain.

As the propellant grain cools, the difference between the thermal expansion of the material near the internal and external surfaces will produce thermal stresses. For design purposes it is only necessary to consider the tangential stress since its maximum absolute value at both the internal and external surfaces is greater than the absolute value of the radial stress which exists somewhere near the middle of the web. The tangential stress σ_t is zero near the middle of the web, but it is high at both surfaces—a compressive stress at the inner surface and a tensile stress at the external surface during cooling.[2]

By writing tangential stress in dimensionless form

$$\Sigma_\theta = (1 - \nu)\sigma_\theta / E\alpha(T_g - T_i) \qquad (10)$$

where ν is Poisson's ratio, E is the modulus of elasticity, and α is the linear coefficient of thermal expansion, it may be plotted[3] as a function of the Biot Number, $\mathfrak{B} = h\,R_e/\lambda$ where λ is the thermal conductivity of the propellant as shown in Fig. 3. The dimensionless stress is somewhat larger for small values of the ratio $m = R_i/R_e$, but in no case does it exceed $\Sigma_\theta = 0.5$, even if the heat-transfer coefficient or $\mathfrak{B}$ is very large.

In contrast, the behavior of a case-bonded grain is radically different. It is again assumed that the solid-propellant grain is an infinitely long hollow cylinder at an initial temperature T_i. At the time $t = 0$ the case temperature is suddenly changed to the value T_g. The grain temperature then gradually changes from T_i to T_g.

If the rocket case initially at 100°F., say, is suddenly changed to a temperature of −40°F., the propellant grain will be placed in compression. Again, only the tangential stress need be considered for design since it is larger than the radial stress. The tangential stress will be a maximum compressive stress at the inside of the grain, decreasing as the radius increases, and suddenly changing to a tensile stress at the outside of the grain where the grain surface has been cooled suddenly to −40°F. As the grain cools with time, the stresses change monotonically until all parts of the grain have reached −40°F. During the cooling cycle, all stresses become tensile stresses as the grain tries to pull away from the case because of the higher coefficient of thermal expansion of the propellant. However, unlike the free-standing grain, the stresses are not zero in the equilibrium temperature condition, in fact, the stresses are then a maximum. The tangential stress is greatest at the inside of the grain and decreases to a smaller finite value at the outside of the grain as the radius increases.[4]

For these conditions, under the additional assumption that the case wall thickness is large or the modulus

(*Continued on page 51*)

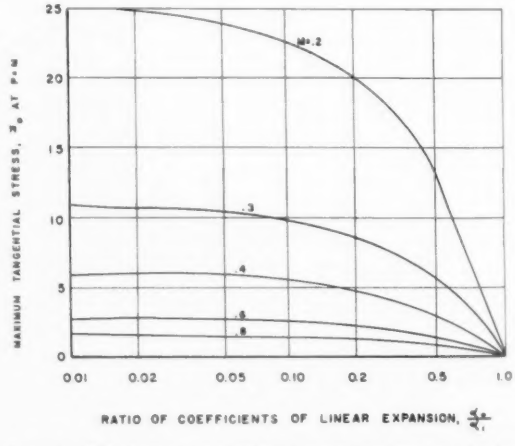

FIG. 4. Maximum tangential thermal stresses at the inner surface of a case-bonded cylindrical grain vs. ratio of linear expansion coefficients for case and grain.

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Unsteady-Lift Functions for Penetration of Traveling Gusts and Oblique Blast Waves

The results of some calculations of the unsteady lift due to the penetration of sharp-edged traveling gusts are presented, and their use in such calculations as that of the lift due to the penetration by a given wing of an oblique blast wave or of the downwash field of another wing is discussed briefly.

Symbols

a = speed of sound of undisturbed air
c = wing chord
C_L = wing lift coefficient
M = Mach Number
Δp = overpressure behind blast wave
s = dimensionless distance traveled, $Ut/(c/2)$
t = time
U = flying speed
U_g = speed of propagation of gust front, positive if opposite to direction of flight
U_b = speed of propagation of the blast wave
w = gust intensity
w_b = speed of disturbed air behind blast wave
x = longitudinal coordinate, positive rearward
x_L = longitudinal coordinate of leading element (foremost point) of wing
x_T = longitudinal coordinate of trailing element (rearmost point) of wing
α = effective local angle of attack of downwash angle (downwash/flying speed)
α_0 = angle of attack in level flight
ρ = density of still air
θ = inclination of blast front relative to longitudinal axis

Introduction

Acknowledge of unsteady-lift effects is required in analysis of many problems of airplane dynamics, such as flutter and response to turbulent excitation. In problems considered in the past, these effects have been expressible in terms of two functions—namely, the lift responses to an abrupt change in angle of attack and to the penetration of a sharp-edged gust, respectively. The first of these functions is substantially identical with the indicial-lift function, which represents the lift response of a wing abruptly accelerated from rest to a given flying speed. It was first calculated for two-dimensional incompressible flow by Wagner[1] and, hence, is often referred to as the Wagner function. The gust-response function was first calculated for two-dimensional incompressible flow by Küssner[2] and is often referred to as the Küssner function. Both functions have since then been calculated for a variety of plan forms and Mach Numbers.[3]

Recently several unsteady-lift problems have become of interest which cannot be analyzed by means of these functions, but which can be analyzed by means of the unsteady-lift response to sharp-edged gusts with fronts that are not stationary relative to the undisturbed air but which translate along the flight path in either direction. Examples of such problems are flight past another airplane (and consequently penetration of its downwash field) in either direction, flight through a sonic boom, penetration of the downwash field of the wing of a convertiplane by one of its rotor blades,[4] flow in a shock tube,[5,6] and flight into or out of a blast wave.[7] (See Fig. 1.)

The unsteady-lift functions for penetration of traveling gusts are more general in nature than the two functions considered previously. Not only do they contain an additional parameter—namely, the rate of travel of the gust front—but they include the two other functions as special cases; they reduce to the Küssner function if the rate of travel is zero and to the Wagner function if it is infinite. They were first calculated for two-dimensional incompressible flow by Miles[4] and then independently, using a different approach, by Hobbs[5,6] and by the present authors.[7] Also, they have been calculated for wings of very low aspect ratio in compressible and incompressible flow and for both two- and three-dimensional wings in supersonic flow.[7]

The purpose of the present paper is to indicate the results of some of these calculations and to discuss their application to some of the aforementioned problems, particularly that of blast penetration.

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Calculation of the Lift Due to the Penetration of Traveling Gusts

For a unit indicial angle of attack the downwash condition is

$$\alpha = 1(t) \tag{1}$$

where $1(t)$ is the unit step function. (For an abrupt angle-of-attack change, the implied abrupt rotation of the wing leads to vertical displacements of its elements and, hence, to an additional downwash term $[(x - x_0)/U]\delta(t)$, where $\delta(t)$ is the unit-impulse or Dirac delta function, and x_0 is the longitudinal coordinate of the axis of rotation.) Similarly, for the penetration of a stationary sharp-edged gust of unit intensity ($w/U = 1$) which is reached by the leading element of the wing at $t = 0$, the downwash condition is

$$\alpha = 1[t - (x - x_L)/U] \tag{2}$$

Now, if the gust front is translating relative to the undisturbed air at a speed U_g in a direction parallel and opposite to the flight velocity, and the encounter of the gust front and the leading element of the wing again occurs at $t = 0$, then

$$\alpha = 1[t - (x - x_L)/(U + U_g)] \tag{3}$$

This relation is also valid if the gust front travels in the same direction as the wing (so that U_g is negative), provided the magnitude of U_g is less than the flight speed U, because the wing can then catch up with the gust. If the gust front travels in the same direction as the wing at a faster speed, the wing cannot catch up with the gust and, instead, the gust overtakes the wing. In this case it is more convenient to let the time reference ($t = 0$) occur at the instant at which the gust reaches the trailing element of the wing, so that then

$$\alpha = 1\{t - [(x - x_T)/(U + U_g)]\} \tag{4}$$

where U_g is now negative and greater in magnitude than U.

It may be noted that both Eqs. (3) and (4) reduce to Eq. (1) when U_g approaches infinity and that Eq. (3) reduces to Eq. (2) when U_g is zero, so that, as mentioned previously, the unsteady-lift function for traveling gusts contains the indicial-lift function and the unsteady-lift function for stationary gusts.

Despite the similarity of the boundary conditions represented by Eqs. (1) and (2), the corresponding unsteady-lift functions cannot be related to each other directly; thus, a knowledge of the indicial-lift function alone is insufficient for the calculation of the lift due to gust penetration. Hence, the unsteady-lift function for the penetration of stationary gusts is usually calculated by a direct solution of the linearized lifting-surface problem for the downwash condition defined by Eq. (2).

An alternative method consists of interpreting this condition as representing a wing with a flap which increases in width at the rate U. The lift due to gust penetration can therefore be obtained from the lift due to indicial flap deflection. (This approach was used in references 2 and 7.) Still another approach consists of using the reciprocity theorems of linearized lifting-surface theory to relate the lift due to gust penetration to the circulation associated with the indicial lift in reverse flow[8] or to the indicial pressure distribution in reverse flow.[9]

The same situation prevails for the lift due to the penetration of traveling gusts; it cannot be calculated from a knowledge of the indicial-lift function alone—

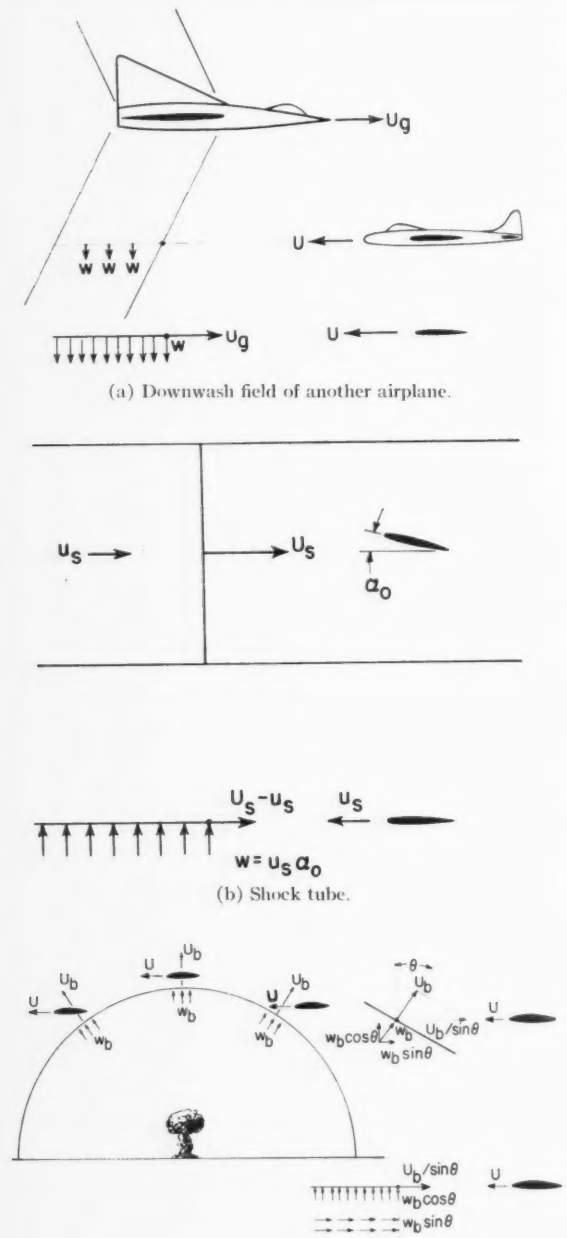
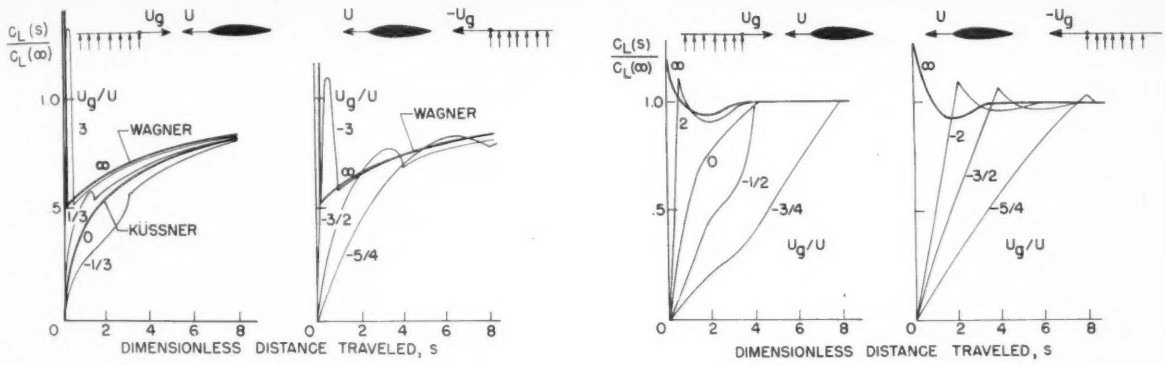


Fig. 1. Examples of problems equivalent to penetration of traveling gusts.



(a) Two-dimensional flow; $M = 0$.

(b) Rectangular wing; $A = 1$, $M = 2$.

FIG. 2. Examples of unsteady-lift functions for traveling gusts.

nor even from a knowledge of both the indicial-lift function and the lift-response function for stationary gusts. Therefore, it must be calculated either directly by solving the lifting-surface problem for the boundary conditions represented by Eqs. (3) and (4) (as was done in references 4, 5, 6, and 7) or by one of the aforementioned alternative methods. The results presented in reference 7 were checked by a calculation based on the lifts due to indicial flap deflections (using the method indicated in the appendix of that paper) and can also be obtained readily from indicial pressure distributions in reverse flow.[9]

The following cases were considered in reference 7: two-dimensional incompressible flow (the case considered also in reference 4 and 5), wings of low aspect ratio in incompressible and compressible flow, two-dimensional supersonic flow, delta wings with supersonic leading edges, and rectangular wings in supersonic flow. These cases represent virtually all the cases for which the unsteady-lift function for stationary gusts has been calculated at present. For all cases the unsteady pitching moment was calculated, as well as the lift.

Some of the results for the unsteady-lift function obtained in reference 7 are shown in Fig. 2, where the unsteady-lift function normalized with the steady-state value is shown as a function of the dimensionless time or distance traveled, with the speed of gust propagation as a parameter.

For two-dimensional incompressible flow, the indicial-lift function (the Wagner function), which in Fig. 2(a) is represented by the curves for $U_g/U = \infty$, contains a concentrated lift impulse at time $t = 0$, which arises from the "potential" (noncirculatory) part of the flow. For large finite speeds of gust propagation (in either direction) this impulse is spread out over a finite time interval, which increases as the speed of gust propagation decreases, with a corresponding decrease in the magnitude of the peak. When the gust speed becomes zero, this peak vanishes altogether, and the lift response is the well-known unsteady-lift function for penetration of stationary gusts. For small negative gust speeds (the case of a wing catching up to a gust front), the peak due to these potential-flow effects is replaced by a dip. The rate of lift increase is smallest when the speed of gust travel is nearly equal in magnitude and opposite in direction to the speed of flight, as may be expected.

The initial impulse in the indicial-lift function and the corresponding large peaks in the lift response to penetration of traveling gusts occur only in incompressible flow. The results shown in Fig. 2(b) for a rectangular wing of aspect ratio 1 at a Mach Number of 2 are thus more typical than those shown in Fig. 2(a). Although peaks still occur in the lift-response functions, they are not much higher than the steady-state value of the lift. Otherwise, the effect of speed of gust propagation on the unsteady-lift functions is similar to that observed in Fig. 2(a).

The presentation of the unsteady-lift functions in the conventional manner employed here—namely, as functions of dimensionless distance traveled—serves to emphasize the difference in the functions for various speeds of gust travel. If, instead, they were shown as functions of a dimensionless *relative* distance

$$s' \equiv (|U + U_g|t)/(c/2)$$

the lateral spread of the curves shown in Fig. 2 would be eliminated to a large extent, and the curves would appear much more similar in nature; however, the curves for $U_g = \infty$ cannot be shown on such a plot, and the variation of the lift-response functions with U_g would be more obscure.

APPLICATIONS OF THE UNSTEADY-LIFT FUNCTIONS DUE TO PENETRATION OF TRAVELING GUSTS

The unsteady-lift functions for the penetration of traveling sharp-edged gusts may find application in a number of problems associated with flight through a moving downwash field. In such a field the entire time history of the downwash experienced by the given wing is known if it is specified at one instant, because the downwash existing at any point x, y on the wing at time t is the same as that which exists at any point x', y

directly ahead of or behind that point at the instant $t' = t + (x' - x)/(U + U_g)$, where U_g is the speed of translation of the downwash field relative to the still air.

In the example shown in Fig. 1(a), for instance, the wing of the airplane at the right encounters the downwash field of the airplane at the left, which is translating at a speed U_g relative to the still air. If the downwash is constant behind the shock front and in the spanwise direction, the unsteady-lift functions discussed herein can be used directly to calculate the lift on the airplane at the right. If the downwash of the airplane at the left varies in the chordwise direction, as it would if that airplane were flying at a subsonic speed, the lift on the airplane at the right can be calculated from the same unsteady-lift functions by superposition—that is, using Duhamel's integral—provided the downwash is substantially constant in the spanwise direction. If the downwash is not constant in the spanwise direction, a more general type of unsteady-lift function (which has the form of a spanwise influence function) is required. Such functions are considered in reference 9 for stationary gusts, and the arguments presented therein can readily be extended to traveling gusts.

In the example shown in Fig. 1(b), as the shock wave passes over the wing, the wing acquires an effective downwash $u_s\alpha_0$ and a "flying speed" u_s. (Although the part of the wing which has not yet been reached by the shock wave has zero "flying speed," it can be considered to be in a flow with speed u_s, provided its angle of attack is considered to be zero.) Hence, the problem is equivalent to an airfoil flying at speed u_s which penetrates a sharp-edged gust with intensity $u_s\alpha_0$ and with a speed of propagation $U_s - u_s$ in a direction opposite to that of the airfoil. Inasmuch as u_s is likely to be extremely small compared to U_s, which is greater than the speed of sound, the flow may be considered to be incompressible in most cases. Furthermore, as another consequence of the fact that U_s is large compared to u_s, the unsteady-lift function will be substantially that for an airfoil penetrating a gust traveling at infinite speed (the indicial-lift function), except that, as noted previously, the concentrated impulse in the indicial-lift function predicted by two-dimensional incompressible-flow theory will be modified to a very high peak of very short duration.

The relation between a blast wave and a traveling gust is indicated in Fig. 1(c). If the airplane is struck from directly below, its effective angle of attack is increased instantaneously by w_b/U, so that the lift developed as a result of this change is the indicial lift. If, however, the airplane is struck obliquely, the elements of its wing are exposed to the new effective angle of attack in a progressive manner, starting with the leading or trailing element, depending on the point on the blast front at which the airplane encounters it. This progressive change is of the same type as that encountered in penetrating a traveling gust.

A small portion of the blast front, which is inclined at an angle θ to the flight path, is represented in the sketch at the right side of Fig. 1(c). From this sketch the effective rate of progress of the blast front along the flight path may be seen to be

$$U_g = U_b/\sin\theta \tag{5}$$

The effective gust intensity in the direction normal to the undisturbed flight path is $w_b \cos\theta$. However, the velocity w_b behind the blast front also has a component $w_b \sin\theta$ parallel to the flight path, which may give rise to significant forces if θ is large—that is, if the blast front is nearly perpendicular to the flight path. Inasmuch as the lift response to a horizontal gust is approximately $2\alpha_0$ times the response to a vertical gust of the same intensity, a combined effective gust intensity, which takes into account both components, is

$$w = (\cos\theta + 2\alpha_0 \sin\theta)w_b \tag{6}$$

As may be seen from Eqs. (5) and (6), if θ is zero, U_g is infinite and w is w_b, so that the problem reduces to the indicial-lift problem, as stated previously. Also, inasmuch as U_b is always greater than the speed of sound, the value of U_g for a blast-penetration problem must always be greater than the speed of sound.

The unsteady-lift functions discussed herein have been calculated by linear theory and, hence, apply only to blasts which are relatively weak by the time they strike the airplane. For such blasts the rate of propagation of the blast front U_b is approximately the speed of sound, and the relation between the blast-induced speed w_b and the overpressure Δp is

$$\Delta p = \rho a w_b \tag{7}$$

In a linearized treatment of the subject, the changes in density, temperature, and entropy across the blast front can be ignored because their effects are of higher order than those considered. However, the overpressure Δp contributes first-order effects to the lift. These diffraction effects have been calculated for some stationary objects[10] but not as yet for airplanes. They are taken into account to some extent in the unsteady-lift functions considered herein but possibly not in their entirety.

For a very strong blast originating at a great distance from the airplane, the blast-induced speed w_b decreases so slowly pursuant to the time of penetration[11] that the results discussed herein for sharp-edged gusts can be used directly. For less intense blasts originating relatively close to the airplane, w_b may decrease sufficiently rapidly to warrant calculation of the lift response by superposition, using the time history of w_b and the lift responses to sharp-edged gusts.

A consideration of Fig. 2 of Eqs. (5) and (6) indicates that the greatest loads, for a given blast intensity, are experienced when the airplane is struck from directly below, as may be expected; not only is the effective gust intensity w then largest but the peaks in the lift response are generally largest for high effective rates of gust propagation U_g.

Conclusions

Several problems have been cited which require for their analysis a knowledge of the unsteady-lift functions associated with penetration of sharp-edged traveling gusts, one of these problems being the pentration of an oblique blast wave. The results of some calculations of such functions by linear theory have been presented, and their application of these problems has been discussed.

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Solid-Propellant Rocket Engineering (Continued from page 46)

of elasticity of the propellant is small, the tangential thermal stress depends on the ratio of the thermal coefficient of expansion of the case material α_0 to the thermal coefficient of expansion of the propellant α_1 and is as shown in Fig. 4 (plotted for $\nu = 0.5$). Again the thermal stresses are larger for small values of the ratio $m = R_i/R_e$, but the most important point to notice is that the thermal stresses are very much greater than for free-standing grains. Thus, for a typical value of $\alpha_0/\alpha_1 = 0.3$, the thermal stresses can be 30 to 40 times their magnitude in a free-standing grain. Development of propellants with mechanical properties that will permit their use in case-bonded grains has been a remarkable achievement of propellant chemistry.

Conclusions

The relatively high performance of modern solid-propellant rockets arises from two principal causes. First is the development of propellants having higher values of specific impulse coupled with mechanical properties that permit them to withstand severe environmental conditions. Secondly we have the integration of the inert parts design in such a way as to optimize the performance of the total rocket-powered system for the specific requirements it must meet.

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"Until aircraft power can be utilized for antigravitational effects, the jet wing offers an attractive means for efficiently utilizing power during all regimes of flight."

The Jet Wing

John S. Attinello*
Fairchild Engine and Airplane Corporation

SYMBOLS

AR	=	aspect ratio = (b^2/S)
b	=	wing span, ft.
c	=	wing chord, ft.
C_L	=	lift coefficient = (L/qS)
C_μ	=	momentum coefficient = (mv_j/qS)
C_D	=	drag coefficient = (D/qS)
C_{D_N}	=	net drag coefficient
C_{D_B}	=	balance-measured drag coefficient
C_{D_i}	=	induced drag coefficient
D	=	drag, lbs.
E	=	lift efficiency $(C_L - C\mu \sin\theta/C\mu \sin\theta)$
L	=	lift
m	=	mass flow (weight flow/g), slugs/sec.
q	=	dynamic pressure $1/2\rho V^2$, lbs./ft.^{2}
S	=	wing area, ft.^{2}
T	=	jet thrust, lbs.
V	=	flight velocity, ft./sec.
v_j	=	jet velocity, ft./sec.
W	=	gross weight, lbs.
α	=	angle of attack, deg.
θ	=	jet angle, deg.
ρ	=	air density, slugs/ft.^{3}
Γ	=	circulation

THE INTEGRATION of the aircraft propulsion and aerodynamic system into a more efficient flight vehicle has been proposed in many ways during aviation's history. The term "jet wing" applies to such a combination for a jet-propelled aircraft. For such a configuration, the propulsive system or jet engine and the aerodynamic surfaces, such as wings, control surfaces, etc., compliment each other in *all* regimes of flight. One of the first steps in this direction has been the use of jet-engine compressor bleed air for flap blowing high lift systems. This technique has been utilized to improve the take-off and landing of high-speed jet aircraft[1, 2] and is currently adapted to several United States and United Kingdom military aircraft in production. This aviation development resulted from research by the U.S. Navy's Office of Naval Research and the Bureau of Aeronautics. In this case, however, a relatively small percentage of the main propulsive power has been utilized for augmenting lift during the landing and take-off phase of flight.

Recent published test results, by both French and British research establishments[3, 4] have renewed the interest in utilizing all the available power of the jet engine for lift production, as well as for thrust. Much of the French and British research resulted from studies of the so-called "jet flap." The jet flap, as its name implies, substitutes a thin spanwise "jet sheet" of air at the wing trailing edge for the well-known physical flap. The advocates of the jet flap, however, discovered that even a small physical flap (over which the jet sheet is directed) is superior for a lift augmentation to the jet flap alone. Both the jet flap and blowing flap have an interesting history.

As early as 1917, Fottinger proposed boundary-layer control by blowing a tangential jet over the upper leading edge of the flap for increasing lift.[5] Ten years later the idea was investigated by Wieland[6] and also by Seewald.[7] In 1931 Bamber conducted NACA tests of a similar system,[8] but practical application of this concept was delayed until about 1956.[9]

The earliest German research in the jet wing field was reported by Hagedorn and Ruden in 1938.[10] In this case, the issuing jet sheet from the airfoil trailing edge effected an airfoil chord extension and manifested itself in an increase in the lift curve slope. These tests were actually conducted only during model calibration for blowing flap research, and the concept of using jet power for lift was not considered at the time.

The earliest jet flap research must be attributed to Schubauer[11] who was searching primarily for jet thrust augmentation possibilities. The configuration of a jet flap which he tested is shown in Fig. 1. He disappointedly reported that "the (thrust) augmentation obtained was insignificantly small" and halted his experiments nearly 25 years ago. His data have been replotted and compared with recent jet flap results in Fig. 2.

The jet flap was rediscovered by both French and English researchers recently—e.g., M. Poisson-Quinton of ONERA and Mr. Davidson of the NGTE. In light

Revised by the author and condensed from the paper of the same title presented at the VTOL-STOL Aircraft Session, IAS 25th Annual Meeting, N.Y., Jan. 28–31, 1957. The original work still is available as IAS Preprint No. 703.

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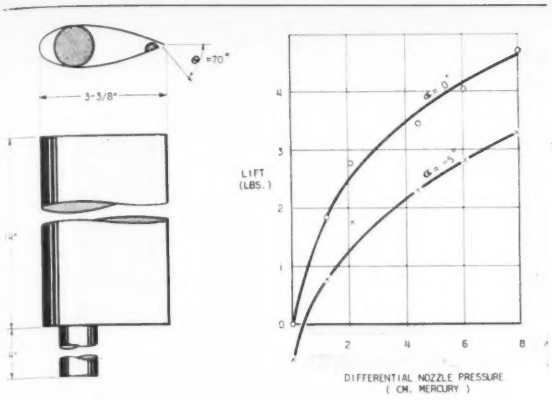

FIG. 1. Schubauer jet flap experiments, 1933.

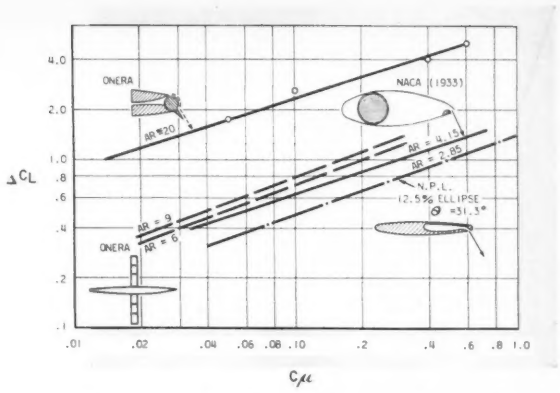

FIG. 2. Comparison of early and modern jet flap experiments.

of suitable and available power sources, in the form of the jet engine, and the great need for such a power-lifting aerodynamic surface, the jet wing has taken on a new importance.

Outwardly the jet wing need be little different from present-day aircraft, except that the exit of the jet engine or engines will terminate in an elongated slot directed over a trailing-edge flap. French, British, and NACA tests have recently explored the jet wing with and without flaps. A small flap appears to be aerodynamically superior and has proved a practical arrangement for orienting the exiting jet angle, which is normally designated θ. Spence[12] has computed the effect of flap-chord ratio and concluded that "the effectiveness of the jet flap scheme might be greatly increased by blowing over flaps of the order of 20 to 30 per cent of the chord, rather than over the very small shrouds which have hitherto been proposed."

Assuming an optimum flap chord is resolved, from aerodynamic and structural considerations, the aerodynamic performance of the jet wing is a function of the jet angle θ and the momentum coefficient C_μ. The latter parameter is defined as the ratio of the momentum of the exiting jet sheet (product of mass and jet velocity) to the product of free-stream dynamic pressure and a reference wing area—i.e.,

$$C_\mu = mV_j/(\rho\, 2V^2S) = T/qS \qquad (1)$$

Fig. 2 compares some early and modern jet flap results by the use of the momentum coefficient. Together with aspect ratio, excellent correlation is obtained from the numerous experimental results available. Fig. 2 also illustrates the adverse effect on ΔC_L when aspect ratio is reduced—i.e., the additional lift increment due to the jet wing configuration. Two and three dimensional ONERA results were obtained from reference 13 and the NPL data from reference 14.

For $C_\mu = 1$, a "ΔC_L" of unity could be obtained simply by direct jet reaction—i.e., by directing the jet efflux vertically downward in the manner of the Flying Bedstead, Ryan Vertijet, and the other jet VTO research vehicles. The weight and complication of the internal ducts required for the jet wing demand that a net gain be obtained for this configuration over direct jet lift. Fig. 3[13] illustrates the jet wing efficiency E plotted against C_μ. For small values of C_μ, the lift increment may be 5 to 10 times the jet momentum expended, and at large C_μ values the lift force may be as much as 2–2.5 times the jet thrust. At infinite C_μ values the efficiency E approaches zero, and then only the vertical component of the jet reaction is obtained. For VTO, therefore, little advantage can be realized for the jet wing configuration if landing and take-off alone are considered.

When military and commercial jet aircraft operate from other than special outlying fields, the noise problem will become increasingly objectionable if the present power and noise trend continues. Again, the jet wing configuration offers considerable promise as an effective method of reducing noise.[15] In Fig. 4, the sound pressure level and frequency are plotted for a conventional circular jet and a two-dimensional or slot-shaped jet. The two jets compared were of equivalent thrusts and exit velocities. The possible reduction of 30 db. in all but the highest frequency range will prove difficult to obtain by other means. Fortunately, the slot jet can also be utilized profitably for flight when incorporated as a jet wing. The high frequency noise is objectionable but is attenuated by relaxation effects[16] to a greater degree with distance than the lower frequencies.

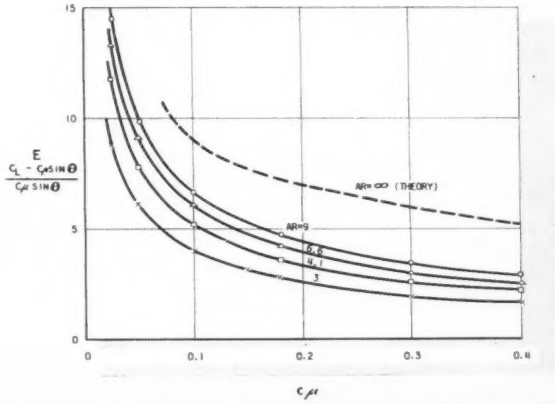

FIG. 3. Aspect ratio effect on lift efficiency ($\alpha = 0° - \theta = 90°$).

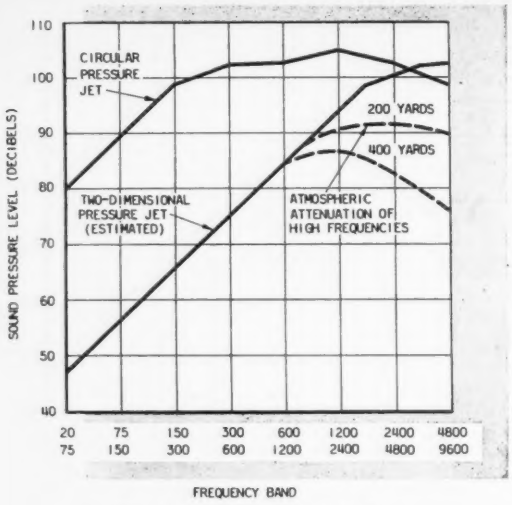

FIG. 4. Jet wing noise reduction.

Two important shortcomings of jet aircraft—the landing and take-off performance and objectionable jet noise on and near the airport—should be markedly improved with a jet wing configuration. These two gains should prove sufficient to justify the necessary development effort. However, an examination of the high-speed possibilities of this configuration should not be overlooked. At high speeds two basic problems always confront the designer, first the reduction of drag and secondly the improvement of control.

Improvement in high-speed control using the jet efflux has proved promising from both tunnel and limited flight tests. The spoiler method shown in Fig. 5[17, 18] is effective over a wide subsonic Mach Number range and, from present indications, appears adequately effective at supersonic speeds. A spoiling or augmenting lift can be obtained by ejecting upward or downward as shown in Fig. 5. Rolling control has been tested in flight by ONERA[19] as an extension of the jet wing concept. The jet flap air source in this case was approximately 1 per cent bleed of the turbojet engine and was directed to the trailing edge of the inboard flaps held at zero deflection.

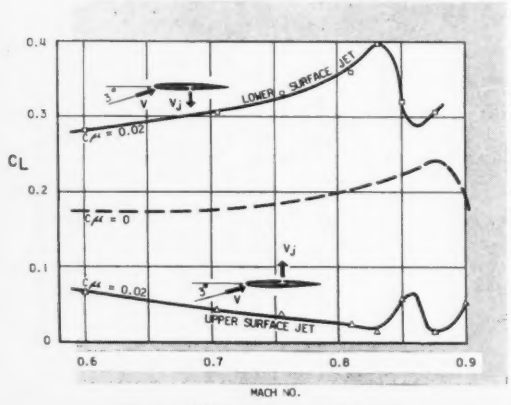

FIG. 5. Effect of jet control on lift.

NACA tests of blunt trailing-edge airfoils with exiting jet sheet have shown improvements in drag.[20,21] Similar results were obtained by ONERA with a blunted, 10 per cent thick wing of aspect ratio 3.[19] It has been found that the reduction in drag due to the exiting jet sheet is slightly greater than C_μ because of improvement of flow at the blunt trailing edge. This improvement continues up to the highest Mach Number tested ($M = 0.91$). The presence of shock waves did not disturb the propulsive jet at the trailing edge.

Increasing the jet angle to 29° produces a lift increase accentuated by compressibility, and a net propulsive force is obtained despite the increase in induced drag. For larger angles of θ, lift is increased to $0.84M$ and drag increases beyond $0.75M$. The lifting efficiency, E at $M = 0.75$ for a $C_\mu = 0.023$, is approximately 17, which is very high. At this Mach Number, however, the C_μ would correspond to considerable thrust for conventional wing areas.

Since the momentum coefficient C_μ is a function of velocity and reference wing area, it may be in order to define this parameter in more familiar terms. From Eq. (1)

$$C_\mu = mV_j/(\rho/2V^2S) = T/qS \tag{2}$$

For level flight the lift coefficient is as normally defined.

$$C_L = W/qS \tag{3}$$

From Eqs. (2) and (3) C_μ may then be defined as a function of the thrust-weight ratio, as

$$C_\mu = (T/W)C_L \tag{4}$$

Fig. 6 graphically connects the general relations of the parameters C_μ, C_L, T/W, and W/S.

Before a solution can be obtained for a jet wing configuration, the C_L–C_μ relation of the wing must be determined. From test results[22, 23] the required values may be obtained for various jet angles. From these data the circulation lift increment can be determined from the relationship

$$C_{L_\Gamma} = (\theta/85)(C_{L_\Gamma})_{85} \tag{5}$$

The total lift is obtained after determining the circu-

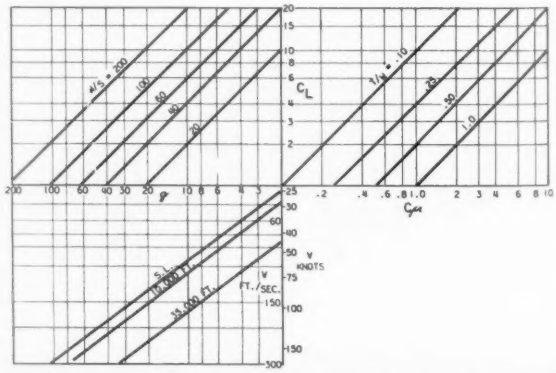

FIG. 6. General relation of functions, C_μ, C_L, (T/W), and (W/S).

lation lift, by the addition of momentum lift, and the lift due to the basic airfoil at an angle of attack, as

$$C_L = C_{L_{C_{\mu=0}}} + (C_{L_\Gamma})_{85}(\theta/85) + C_\mu(\sin\theta + \alpha) \quad (6)$$

The graphical solution of the equations is illustrated by Fig. 7. The example selected is for a jet wing of aspect ratio 6 at zero angle of attack; for two jet deflecting angles, $\theta = 85°$ and $45°$; and for two values of thrust to weight ratio, $T/W = 0.25$ and 0.50. For wing loading of 60 lbs./ft.^{2}, level flight speeds at sea level of approximately 50 knots will be realized for $T/W = 0.25$ or 39 knots for $T/W = 0.50$. This exercise is a simple illustration of the jet wing potential with respect to low speeds. Thrust recovery considerations must be taken into account for take-off, wave-off, and engine-out conditions, hence the choice of jet angle must be determined by other than lift considerations.

The aerodynamic, thermodynamic, and structural problems of the jet wing are only now receiving serious attention. From all present indications the advantages of the jet wing merit the required research effort to bring a practical configuration to the operational stage. Until aircraft power can be utilized for antigravitational effects, the jet wing offers an attractive means for efficiently utilizing power during all regimes of flight.

EDITOR'S NOTE: Attention of the reader is invited to the following presentation at the Annual Meeting which was made as a contribution to the investigations discussed herein.

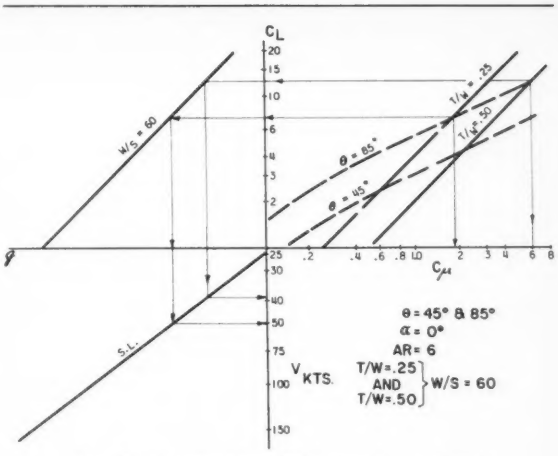

FIG. 7. Jet wing level flight speeds at sea level.

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EDITOR'S NOTE—*This paper was presented at the 25th Annual Meeting as a contribution to the investigations discussed in the preceding report by Mr. Attinello.*

Some Remarks on the Jet Wing and VTOL Aircraft

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ALTHOUGH it may be usual to consider the "jet flap" or "jet wing" in the context of VTOL and STOL problems, it is worth remembering that it can also be regarded as one solution of a wider problem—namely, the integration of the lifting and propulsive systems of an aircraft. Such a concept naturally includes the property that the take-off and landing performance of the aircraft is less limited than with a conventional design.

In the conventional approach, the means of production of the lift and thrust forces are considered separately. This appears "unnatural" if one considers the flying animals which invariably operate with an integrated system.[1] Special biological conditions lead to limitations to which engineering techniques are not subjected so that the engineer need not copy the birds in order to obtain the same results. This leads to the "thrust wing,"[2] a typical VTOL aircraft—in effect, a helicopter at take-off and landing and a lightly loaded propeller in pitch with a high rate of advance in level flight. The theory of such wings was brought to about the same level as classical airfoil theory.[3]

A more compact arrangement is obtained if the "wing" is enclosed in a fairing so that the interference between the wing system and the fairing (annular) is such that the latter takes part of the thrust and lift forces. A theory of such a ducted airscrew exists,[4] and a VTOL aircraft on this basis was proposed as long ago as 1944 by Betz and Reiniger.[5] This line of development leads to the "coleopter."[6] There is also a good deal of unpublished work done on these problems in the United Kingdom during this time.

The interference may be such that the actual forces are carried entirely on the fairing—as with the ramjet—and the fairing need not be annular but can take the shape of a flat wing. This leads to the "jet wing," which has been discussed in this context with particular reference to duct losses which necessarily become important.[7, 4] With this use of the jet—which is not boundary-layer control—it is possible to achieve a large asymmetry in the flow and hence very high lift forces while retaining a large proportion of the thrust. These important properties—viz., the powerful circulation control and thrust recovery—were recognized and developed by Davidson[8] in the "jet flap" scheme.

After Davidson's demonstration of the possibilities of the jet flap, interest at the Royal Aircraft Establishment was directed toward the develoment of a theoretical background, the results of which can be summarized as follows:

(1) Consideration of the basic physics of the flow clarified the relations between the forces on the airfoil and the jet parameters.[9] This included the relation between the circulation about the jet and its momentum and curvature and also established that the momentum of an infinitely thin jet is necessarily constant along its length.

(2) On this basis, classical theory was extended to deal with the case of a thin airfoil with an infinitely thin jet emerging at a small angle from its trailing edge.[10] This theory led to the formula

$$C_L = A(C_J)\tau + B(C_J)\alpha$$

where

$$A(C_J) = 2\pi^{1/2}C_J^{1/2} + 0.325C_J + 0.156C_J^{3/2}$$
$$B(C_J) = 2\pi + 1.152C_J^{1/2} + 1.106C_J + 0.051C_J^{3/2}$$

approximately, and where

C_L = overall lift coefficient

$C_J = \dfrac{M_J}{(1/2)\rho V_0^2 c}$ = momentum coefficient

τ = deflection angle of the jet

(3) The same theory has also been extended to include the thin airfoil with a hinged flap.[11]

(4) A method for the rapid calculation of the pressure distribution over the airfoil for given values of lift and thrust has been developed.[12] In this method, account can be taken of thickness, camber, and three-dimensional effects, provided that the latter are known.

(5) Three-dimensional wing theory has been extended to cover the jet flap problem.[13] The main result of this is that the induced incidence of the wing is reduced by the blowing, but the effectiveness of the jet as a lift augmenter is also reduced as a result of the finite

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span. At a given lift, the induced drag is smaller than for a plain wing, according to the formula

$$C_{Di} = \frac{C_L^2}{\pi.1 + 2C_J}$$

On this basis a coefficient for the viscous form drag can be defined as

$$C_{D0} = C_D - C_{Di}$$

where $C_D = C_J - C_T$ = total drag of the three-dimensional wing, C_J = ideal thrust of the two-dimensional section in inviscid flow, and C_T = resultant thrust force on the three-dimensional wing. Analysis of the few available experiments suggests that C_{D0} is independent of aspect ratio and incidence, provided that significant flow separations on the wing are avoided.

Apart from the obvious advantage of the jet flap system that it can lead to an aircraft where the means of producing lift and propulsion are integrated, several aerodynamic advantages have become apparent. The saddleback chordwise loading, which is typical of the airfoil with jet, allows C_L values to be obtained without flow separation, which can be about twice as high as when the lift is created by putting the airfoil at an angle of incidence. Further, this particular type of loading, with its rear suction peak not easily affected by flow separations, allows the use of thickness and camber near the leading edge to an extent which is not normally possible on ordinary airfoils, whereby the lift obtainable is increased further. Lastly, when separation near the leading edge occurs, the resulting bubble can be shorter and the leading-edge suction higher than on ordinary airfoils, again because of the basic saddleback loading.

Altogether, it would appear that the thrust wing—possibly in the form of the coleopter—and the jet wing are the most promising extremes of integrated aircraft systems.

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It is pointed out that sled testing performs a dual function for the flutter engineer—a check on the theoretical calculations and a final measure of the margins of safety of the new design.

The Application of Rocket Sled Techniques to Flutter Testing

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Introduction

In recent years, flutter has grown from a problem of secondary importance into one of the most fundamental considerations in the design of high-speed airplanes and missiles. This evolution in the importance of the flutter problem has resulted in greatly expanded efforts on the part of both industry and research to find means of adequately assessing the effects of flutter at an early stage in a new design and to determine methods by which the design may be constantly checked as it progresses ultimately to the flight-test stage. These activities have yielded a number of significant improvements in flutter theory, and, in particular, the field of unsteady aerodynamics has been notably expanded by this work. Developments in experimental methods have tended to parallel the theoretical research as evidenced by the increased use of wind-tunnel facilities for the determination of the flutter characteristics of models over wider ranges of Mach Number and the availability of experimental equipment which enables more accurate and refined vibration testing both on the ground and in flight. As a logical part of these developments in test methods there has come finally a new and promising tool for the flutter engineer—namely, the rocket sled. The rocket sled flutter test fills a wide gap in the flutter design process which now, and in the future, must be based on a "concept to flight" philosophy. It is the purpose of the present paper to review the fundamental reasons for this type of testing and to outline a number of the details of the test methods and equipment which are currently employed in the accomplishment of such tests.

A condensation of the paper of the same title presented at the Aeroelasticity—II Session, IAS 25th Annual Meeting, N.Y., Jan. 28–31, 1957, and at the Third Annual Supersonic Track Symposium, China Lake, Calif., Sept., 1956. The authors' complete work is available as IAS Preprint No. 666.

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Fig. 1 (*left*). Vertical tail installation on general-purpose rocket sled. Fig. 2 (*right*). Horizontal tail installation on general-purpose rocket sled.

The Rocket Sled Flutter Test

Up to this time, there has never existed for the flutter engineer a test technique which would enable flutter actually to occur on a full-scale structure. He has been forced to rely, for a quantitative prediction of the flutter condition, on theoretical analysis and model data as confirmed by full-scale vibration checks on the ground and in noncritical portions of the flight regime. With the advent of high-speed track facilities, however, this latter type of test has become a reality, and it has now become possible to evaluate the flutter characteristics of a new design on the full-scale article without risking the possible loss of an aircraft or human life.

There exists a direct correspondence between strength design and flutter design, and prior to proceeding with a detailed discussion of rocket sled flutter tests it is well to point out that this type of test has an exact counterpart in the field of structural strength determination—namely, the well-known static test to destruction. It should be noted that both tests are based on an identical philosophy and that both fulfill a similar purpose in the process of evolving and proving a given structural configuration. Both tests have two main objectives. The first of these is to permit an evaluation of those effects which cannot be accounted for on the basis of theory or by the use of model tests. These may include such items as abrupt structural discontinuities, hysteresis, and nonlinearities in the control system. The second purpose of these tests is actually to determine the exact conditions for structural failure and hence to establish without doubt the true margins of safety. Both the rocket sled flutter test and the static strength test are usually performed at a stage in the design at which the structural configuration may be considered as final. Ideally, such tests should be conducted in advance of the first flight of the prototype and under no circumstances should the flight program be extended to include the maximum load and performance limits until the strength and flutter tests have been completed.

In a rocket sled flutter test, the test component is mounted on a rocket-propelled vehicle in a manner which adequately reproduces the details of the actual aircraft installation. (Typical installations are shown in Figs. 1 and 2.) This includes not only the attachment structure but also a fully operative control system complete with all the necessary actuating devices and accessories. In many cases, it may be necessary to employ a major portion of the actual aircraft structure in order to realize the desired degree of simulation. For example, in performing flutter tests on tail structure, the complete rear fuselage may be incorporated into the sled configuration if the aerodynamic and structural effects of the fuselage play a significant part in determining the flutter stability of the tail.

The test program itself consists of a series of runs which are conducted in a "build-up" fashion to successively higher and higher speeds until flutter is obtained (Fig. 3) or until the test article has demonstrated an adequate margin of safety. Adequate excitation of the lifting surface normal modes is obtained from the small random vertical and lateral motions of the test carriage. It is apparent that the results of the flutter test are strictly applicable to the airplane only at an altitude corresponding to the elevation of the test facility above sea level. This apparent disadvantage of the method is offset by two factors:

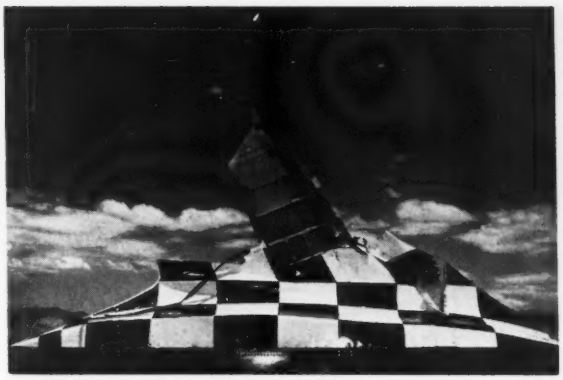

Fig. 3. Flutter damage.

(1) It is possible to predict altitude effects on flutter with a reasonable degree of certainty by theoretical means.

(2) In most practical cases the critical flight condition for flutter occurs in the transonic range at low altitude, hence the sled test will reproduce very closely the actual flight situation upon which the flutter design is based.

The major problems in a rocket sled flutter test arise as a result of the fact that the pertinent flutter data must be obtained in a very short interval of time and recorded at a location remote from the test specimen. In addition, the speed time history of the sled must be very carefully programed in order to ensure that a steady speed build-up is achieved from one run to the next. This necessitates a careful choice of the rocket configuration and the firing sequence. Finally, the high-speed portion of the run must be carefully controlled in order that the sled may be safely stopped in the available track length without imposing extreme loads on the structure of the test article or carriage.

The Test Sled

In undertaking rocket sled flutter tests, careful attention must be given to the design of the test vehicle since the ultimate success of the program will depend, to a great extent, on this single item. Flutter test sleds may be classified as general-purpose or special-purpose vehicles. The general-purpose sled is employed normally in test programs where several lifting surfaces of comparable size are to be evaluated and where the flutter characteristics of these surfaces do not depend primarily on such factors as fuselage flexibility, rigid body motions, or aerodynamic interference from other parts of the air frame. This type

of sled serves as a common carriage for all of the test articles, and, in general, it greatly eases the problems of instrumentation, rocket installation, and ballistic performance estimation. In addition, the overall program is expedited considerably by the use of such a vehicle. Figs. 1 and 2 illustrate typical flutter test installations on a general-purpose rocket sled. The special-purpose sled, on the other hand, is used in cases where the duplication of a major portion of the air frame is deemed necessary in order to obtain realistic test results. In such instances, the sled and lifting surface are designed normally as an integral unit. The installations of rocket motors and instrumentation must be suited to the configuration of the test article, and they must involve minimum aerodynamic and structural modifications. This latter type of sled is normally of use only in a single-test program, hence much care must be taken with the performance calculations in order to ensure a uniform speed build-up at a reasonable rate. The performance estimation problem is not as acute for the general-purpose sled since data from previous tests will lend increased precision to the analysis.

Regardless of the particular type of test sled employed in a given program, there exist a number of common features and functions which should be kept in mind when proceeding with the sled design. The sled will carry normally a complement of rocket motors which must be easily installed, readily accessible, and suitably wired for multistage firing. In addition, the test vehicle must house all the necessary instrumentation and associated power supplies. This will include, in most cases, a reasonably comprehensive telemetering setup, high-speed cameras, and appropriate range timing devices for speed determination. If aircraft accessories or components are to be carried, sufficient space must be provided for the installation of this equipment. External electrical knife contacts must be fitted in order to initiate specific events during the run. Finally, it will usually be necessary to make provision for some form of braking device such as a water brake or reverse thrust rocket in order to ensure a safe recovery of the vehicle and its contents.

The structural criteria used in the design of the rocket sled structure are straightforward and simple. The primary structure must be capable of withstanding the loads imposed during starting and braking. It should be noted that for specified maximum speeds on a particular range these loads are in direct proportion to the total weight of the sled, test article, rockets, instrumentation, and associated equipment; hence, special attention must be given to weight growth at all phases in the design.

In order to have the test successfully concluded, destructive flutter of the lifting surface must occur. This requires that the basic sled structure be capable of enduring loads in excess of those required to fail the test article. These loads may be estimated with reasonable accuracy from a knowledge of the static strength of the lifting surface, and they should be applied in a direction consistent with the mounting of the surface on the carriage. The fact that flutter failure of the test surface is anticipated poses still another consideration in the sled design. Such failures, when they occur, are frequently quite violent, and therefore the external surfaces of the sled should be adequately designed to prevent major damage from flying debris. If at all possible, external equipment such as camera, telemeter antennas, and electrical contacts should be located in areas where the possibility of damage from this cause is remote. If this is not practical, suitable protective shields should be provided.

The aerodynamic features of the sled are as important in contributing to the ultimate success of the flutter test as the structural characteristics. The flow in the vicinity of the lifting surface must closely duplicate that which would be obtained in flight, hence aerodynamic interference arising from the carriage, external equipment, rocket blast, and the ground must be kept to a minimum. In addition, the sled itself should be designed for minimum aerodynamic drag in order to reduce the thrust requirements and thus ultimately the total weight. External protuberances should be avoided if possible, and, in the event that they are necessary, suitable streamlining should be provided. Care should be taken to avoid "choking" between the bottom of the sled and the ground at transonic speeds since this will give rise to major increases in drag. This phenomenon may be avoided to some degree by providing for flow escape in this area. This may be accomplished by venting the sled bottom, raising the bottom above the rails, or the use of a "Vee" bottom. For sleds designed to operate in the transonic range, it is conceivable that some measure of drag reduction could be achieved by utilizing the area rule concept as applied to high-speed aircraft. Supersonic drag, on the other hand, may be minimized by the use of high fineness ratios, small wedge angles, and the general avoidance of contours which would tend to produce strong shock waves. It should be noted that, in addition to minimizing the drag which results from the sled shock patterns, clean aerodynamic design will generally reduce unwanted aerodynamic interference with the test article.

Instrumentation and Data Reduction

The success of any engineering test depends not only on the reproduction of a realistic environment but also on the adequate determination and interpretation of the physical behavior of the test specimen. The rocket sled flutter test is no exception in this respect, and suitable instrumentation is necessary in order to observe and measure the motions of the lifting surface during the entire high-speed portion of the run. In addition, a continuous record of range time, distance, velocity, and acceleration—suitably correlated with the remaining data—must be obtained.

In flutter, the motion of the structure is of primary concern, hence the test measurements will be devoted to a determination of the flutter mode shape, the flutter frequency, and the speed at which the instability occurs.

The mode shape and frequency may be readily obtained if time histories of the structural deflections at a number of points on the surface are known. For this purpose, either accelerometers or strain gages may be used.

Regardless of the type of transducers which are provided in a specific test, a suitable means of transcribing and recording the transducer output data must also be incorporated into the overall instrumentation system. This may take the form of sled-borne recording equipment of either the photographic or electromagnetic type. This method has the distinct advantages of simplicity and compactness, although all too often the equipment is not designed to function under the load and acceleration conditions which normally accompany a high-speed rocket sled test. As a result of this latter fact, the recording equipment must be stationary and thus remotely located from the sled itself. The direct connection between the transducing and recording elements must then be provided by a telemetering system. This involves the installation of the necessary oscillators, transmitters, antennas, power supplies, and cabling in the test sled; and it requires the provision of a ground receiving station complete with discriminators and recording devices. A typical sled-borne telemeter system is illustrated in Fig. 4.

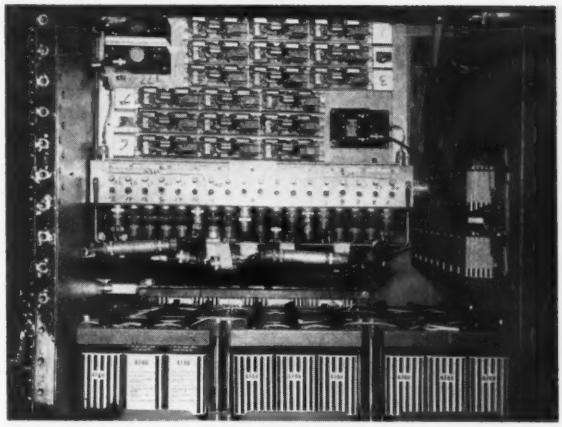

FIG. 4. Typical telemeter installation.

As a further aid to determining the nature of the lifting surface motions during flutter, high-speed photography is invaluable. Cameras may be mounted on the sled in order to view the test surface in its own frame of reference, and they may be placed in fixed installations along the track. In the latter case, the range distance and field of view are preset on the basis of the best available prediction of the sled position at the time of flutter. The frame speed of the recording cameras must be sufficiently high to permit an adequate examination of the motion on an extended time scale.

The maximum frame speed is set by the available length of film and the required duration of camera coverage. Adequate allowance must be made in the camera running time for the initial acceleration period which is necessary in order to bring the sled up to speed, for the high-speed portion of the run and for at least 1 sec. of the coast phase. The sled-borne cameras are normally started as a part of the initial firing sequence since any attempt to start the equipment during the acceleration phase will usually result in either mechanical malfunctions or a prolonged run-up to the desired frame speed. Electrical power to each camera must be shut off prior to the end of the sled run in order to prevent excessive damage to the free end of the exposed film as it revolves on the take-up spool.

In addition to the above instrumentation which is used to measure and record the flutter motions of the lifting surface, further equipment must be provided to enable an accurate determination of range distance, range time, velocity, and acceleration. It is extremely important that these data be suitably correlated on a time or distance basis with that which is obtained from the other test instruments. It is conventional to employ fixed track equipment for the primary determination of distance-time data and the associated derivatives.

Time correlation with the photographic data is obtained by the use of a high-frequency timing light which marks the film at regular time intervals; and the corresponding distance correlation may be accomplished by the use of visual displays at fixed stations along the track. It should be noted that the camera frame speed should not be depended upon to give a reliable measure of elapsed time since this will vary somewhat with supply voltage, film length, and sled acceleration.

A final and important part of the instrumentation in any rocket sled test is the meteorological equipment for the determination of atmospheric conditions prevailing at the time. These data consist of wind velocity and direction, barometric pressure, and temperature. From this, the sled velocity at the time of flutter may be corrected to equivalent still air conditions and the flutter Mach Number and indicated air speed may be determined. This equipment should, if possible, be located near the expected flutter point and should be monitored continuously before and during the test run. It should be noted that last minute changes in the rocket motor configuration may result from variations in the atmospheric conditions.

OPERATIONAL TECHNIQUE

It has been previously mentioned that the rocket sled flutter test must be conducted in a "build-up" fashion. In such a procedure, the speed is increased gradually from a value well below the expected flutter speed until the final flutter condition is reached. This is done in a series of successive runs with the maximum speed in each run set to exceed that of the previous run by some reasonable increment. The size of these increments and the maximum speed that may be attained in a given test program are determined invariably by the sled characteristics and the total length of track available. The sled run is composed of several phases, and the sum of the track distances required

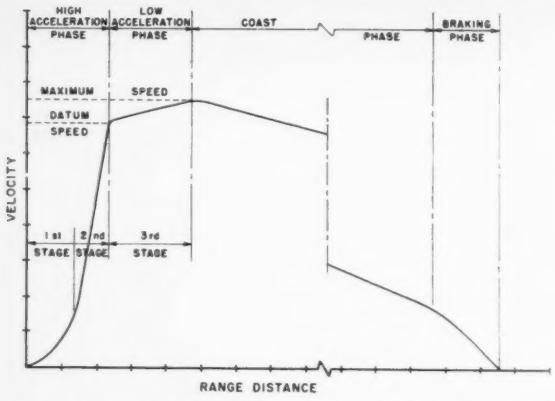

FIG. 5. Velocity-distance plot, typical rocket sled flutter run.

for these various phases shall not exceed the overall track length.

In general, a typical sled run in a flutter test program will consist of (1) one or more initial acceleration phases, (2) a final low acceleration phase terminating at the maximum speed desired for the run, (3) the coast phase, and (4) the braking phase. (See Fig. 5.)

During the initial phases of the run, the object is to bring the sled to a datum speed at which point the low acceleration phase can be initiated. In order to conserve valuable range distance, the accelerations during the initial phases should be as high as the structure of the sled and test article will permit. Frequently, it is necessary to employ two or more stages in order to maintain the allowable acceleration for a sufficiently long period of time to reach the required datum speed. The length of any given stage, of course, is determined by the rocket burning time. Multistage operation in this phase of the run is often accomplished by the use of a separate "booster" sled. In this case, the auxiliary sled carries only rocket motors, and these are fired as the first stage. The advantage of this method is that the burned-out first-stage rocket motors do not constitute dead weight items which must be accelerated by the later stages since the booster is physically disconnected from the main sled at the instant the second stage is fired. The main sled weight is reduced by this type of operation, hence a net saving in the thrust required for the later stages is afforded. This, in turn, permits a further weight-saving by enabling a reduction in the number of rocket motors which must be carried on the test vehicle. It is always advantageous to minimize sled weight in order to permit an increase in the allowable braking decelerations and thus a shorter braking distance. A reduction in the number of main sled rocket motors also reduces the complexity and size of this vehicle—an asset which cannot be overlooked.

As mentioned above, the initial acceleration stages terminate with the attainment of a datum speed from which the test vehicle is accelerated slowly to the maximum speed for the run. The acceleration in this latter phase is of the order of 1g, and the speed increment from datum speed to maximum speed should not exceed 40 knots. This procedure is adopted in order to permit a smooth and continuous coverage of the subcritical speed range up to the flutter condition and a more precise determination of the speed at which the instability occurs. It is apparent that this objective may be achieved if the datum speed for a given run is set equal to the maximum speed obtained in the previous run. The speed build-up from one run to the next is accomplished, therefore, in the final low acceleration phase. This particular method has been found superior to the so-called "stepwise" technique in which the maximum speed is reached at the end of the high acceleration phase and then sustained at a nearly constant value for a brief period of time. In this latter procedure, the maximum speed and the datum speed are essentially equal. It has been found from wind-tunnel, shock-tube, and early sled flutter tests that, when a lifting surface is accelerated rapidly, the flutter speed will be substantially increased above its "steady state" value. In airplane design, it is this minimum flutter speed which is of importance, hence any test technique which employs rapid accelerations into previously unexplored speed ranges may yield misleading results. The stepwise method accomplishes the speed buildup by merely extending the duration of the high acceleration phase from one run to the next. Unless the speed increments used in this process are extremely small, a strong possibility exists that the desired flutter speed will be reached and surpassed in the acceleration phase. In such a case, flutter will not occur until the maximum speed for the run is attained and the acceleration drops to zero during the sustained speed phase. Under these conditions, the maximum sustained speed will exceed the critical speed for flutter and an extremely violent divergent motion of the lifting surface will result. The actual flutter speed can never be determined precisely by the stepwise method since it will invariably fall between the maximum speed obtained in the final run and the maximum speed of the run immediately preceding in which stability was observed. The accuracy of flutter data obtained in this manner is dependent, therefore, on the magnitude of the speed increments which are used in the build-up process. If the increments are large, a high degree of uncertainty will surround the final answer, whereas if the speed increments are reduced in size for reasons of accuracy, a large number of sled runs will be required in order to cover a given speed range. Further, it should be pointed out that the accuracy of the methods which are used to predict the sled performance in advance will, to a large extent, set a lower limit on the size of these speed increments. The "low acceleration" technique permits the coverage of a wide speed range with relatively few runs, and yet in any given run it allows ample time for flutter to occur under essentially steady-state conditions.

When the last stage of rocket motors has burned out, the coast phase begins. This phase ends when the

(*Continued on page 77*)

"Reliability of electrical control systems has been improved considerably thus far, and efforts are continuing. At such time that the reliability of electrical control systems can be made to equal that of mechanical systems, it is firmly believed that all high-performance aircraft will be 'flying by wires.'"

Analysis of an Electrical Flight-Control System for Interceptor-Type Aircraft

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Introduction

Convair, San Diego, A Division of General Dynamics Corporation, has believed for some time that airplanes would some day use "fly by wire" control systems. Because of this belief, a program for research and development of an electrical primary control system for advanced aircraft was initiated.

The control problems which led to serious consideration of electrical systems are many and varied. An example is that of making a control system which will enable the pilot to fly equally well throughout the entire flight regime of the aircraft. For transonic flight at low altitudes, where control surfaces are extremely effective, the control system should move the surfaces very slightly for an incremental pilot force. However, at take-off, large surface deflections are required. Thus, a factor of 20 may exist in the force-displacement gradient between these two conditions. This basic requirement presents control problems which—when complicated with long fuselages, engine vibrations, divergent phugoid conditions, cockpit capsule design requirements, bob-weight effects, altitude, temperature, and radiation—can make it difficult to design a satisfactory mechanical control system.

System Dynamic Analysis

Several types of electrical control system were considered. These may be described briefly as (a) an electrical equivalent of a typical mechanical system, (b) a closed-loop system using an airplane rate feedback, and (c) a closed-loop system using an airplane position feedback.

Considering the merits of these systems by analysis, we decided that the advantages offered by a closed-loop rate feedback system warranted an intensive study to determine the applicability of this type of system to high-speed, high-altitude aircraft. Some of the advantages of this type of system are a fully maneuverable airplane, a minimum of programing to obtain the desired flying characteristics (constant stick force per g and positive trim stability), reduction of weight over the mechanical system, and a degree of flexibility previously unobtainable with control systems.

This rate feedback system was then examined in order to determine the most efficient form of feedback to be used. To select the gains that should be used, an analog computer was employed to simulate a typical airplane and its control system. The flight conditions which were initially investigated were such as to cover the flight range of present-day interceptors. The system which performed most effectively throughout the operating range is shown in Fig. 1. This system for the longitudinal mode is

$$\delta_e/\dot{\theta}_e = K_1 + (K_2/S)$$

For the flight conditions investigated, the most desirable gains for K_1 and K_2 were found to be

For pitch

$$K_1 = 0.6 \text{ deg./(deg./sec.)}$$
$$K_2 = 2.0 \text{ (deg./sec.)/(deg./sec.)}$$

For roll

$$K_1 = 0.2 \text{ deg./(deg./sec.)}$$
$$K_2 = 0.6 \text{ (deg./sec.)/(deg./sec.)}$$

After these initial analog computer results were obtained, the system was tested by having pilots "fly" the simulated airplane. In order to give the pilot some

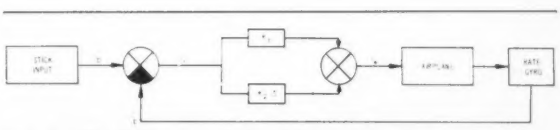

Fig. 1. Block diagram of closed-loop system [where $\theta_e = \theta_D - \theta_0$; $\delta_e/\dot{\theta}_e = K_1 + (K_2/S)$].

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* Senior Dynamics Engineer, San Diego.

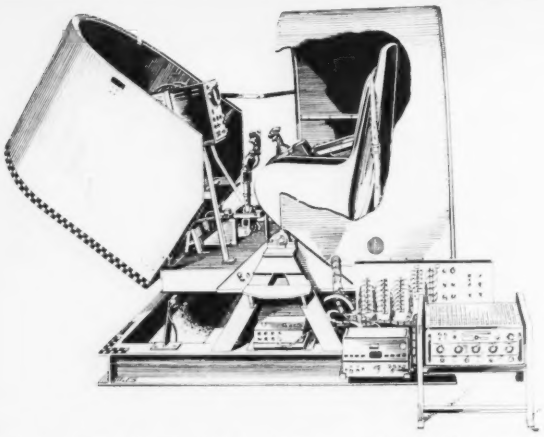

FIG. 2. Cockpit test stand. (For conventional stick details, refer to Fig. 3.)

feel of actual airplane motion, a moving cockpit test stand was used to demonstrate and evaluate the various electric stick configurations. This moving cockpit test stand is shown in Fig. 2. The motion of the moving cockpit test stand was limited to one rotational degree of freedom which simulated the pitching motion of the airplane. The cockpit was moved by an electrically operated servovalve controlling a hydraulic actuator. The pitching rate of the cockpit was limited to about 50 deg./sec., and this necessarily limited the natural frequency of the system to about 1 cps with a full cockpit motion of $\pm 10°$.

In addition to the cockpit movement, another hydraulic actuator permitted the center stick in the cockpit to be moved by another electrically controlled valve-actuator combination. The purpose of this was to allow greater flexibility in the representation of the stick motions to the pilot. The stick either could represent any spring constant for the deflection vs. force gradient or could be made to represent pure surface motion reflected to the pilot.

Two sticks were installed in the cockpit to allow the pilot to fly the electrical control systems with either a center or a side stick. These two sticks can be seen in Fig. 2. The force transducer in the main control stick may be clearly seen in Fig. 3. It was this force sensor which allowed any force gradient to be represented and also made possible the evaluation of a force stick steering system.

Evaluation of Systems

To evaluate the relative merits of the various systems using different gains and different feedbacks, the following method was used: A pilot was given a specific task to do for a certain time while a continuous disturbance was introduced to keep the task dynamic. An evaluation circuit was then used to measure the effectiveness of the pilot and system combination.

Two types of task were presented to the pilot—the first consisted of having a pilot attempt to hold a constant attitude to represent basic instrument flight, the second increased the task difficulty as time progressed to simulate an interceptor closing on the target. Of the two tasks, the intercept problem was the more difficult, and for that reason it was used more often.

The continuous disturbances used were generated by a white noise generator. One type of disturbance used produced the effect of traveling through rough or gusty air. This would incessantly change the angle of attack of the aircraft which in turn would disrupt the attitude. In order to simulate reasonable gust conditions, the noise was filtered with a first-order low-pass filter of the time constant τ_G. The value of τ_G was nominally chosen to be

$$\tau_G = 0.3/\text{Mach Number}$$

and the equation for rough air disturbances was

$$\Delta \alpha_{\text{gust}} = \frac{K}{1 + (0.3/\text{Mach Number})S} x \text{ (white noise)}$$

where K adjusted the severity of the gust conditions. Another type of disturbance used moved the target airplane with a filtered function of white noise which corresponded to evasive maneuvers of a target.

The evaluation circuit used integrated the absolute error of the angle between the airplane x-axis and the line-of-sight to the target. The integral of the absolute value was chosen for two reasons:

(1) It was easier to generate on the computer than the integral of the error squared [which, divided by duration of task, gives r.m.s. (root mean square) error].

(2) It presented the same information as does r.m.s. and can be linearly related to r.m.s. when the error can be assumed to have a Gaussian distribution.

To present the two previously mentioned tasks to the pilot, two different displays were placed on an oscilloscope. For the constant attitude task, the scope presentation consisted of a short line to represent the airplane and a long line to depict the horizon. Two varia-

FIG. 3. Conventional stick details.

tions to this display included an "inside-out" presentation and an "outside-in" presentation. The inside-out presentation is interpreted to mean that the pilot is rigidly attached to the airplane and the display would be that part of the horizon which the pilot would see; the horizon would move while the airplane remained fixed in the middle of the scope. The outside-in display assumed that an observer was standing on the horizon directly behind the airplane, and the motions which the airplane performed, as seen from the observer's vantage point, were projected upon the scope. Both variations of the displays have been used, and it appeared to be personal preference that determined which presentation was used because both pilots and nonpilots like each type.

The display for the intercept problem was slightly more complicated and is illustrated in Fig. 4. The steering dot represented the target airplane, and the task was to maintain the steering dot in the steering circle. The position of the steering dot corresponded to the angular error between the line-of-sight to the target and the airplane x-axis. The steering circle represented an error of about 0.75° from the airplane x-axis and did not move from the center of the scope during the tests. The range circle converged with time, and, when the range circle was the same size as the steering circle, the display changed to an x to simulate firing of the armament and completion of the task. The average time of task was 1 min. The horizontal reference indicated the angle between the airplane y-axis and the plane of the horizon. The preference for an inside-out or outside-in display of the horizontal reference again appeared to be a matter of personnel preference, and again both methods were used.

Results of using the integral of the absolute error (described earlier) as the scoring system indicated that use of the electric stick resulted in as good a score as it was possible to attain when using a perfect mechanical system. It was noted that pilots would invariably receive a higher score than nonpilots although with continued practice it was possible for the nonpilot to improve his score appreciably. There appeared to be a learning period of 2 or 3 min. (corresponding to flying a 1-min. task two or three times) before a person would begin to get consistent scores. This seemed to be as much the learning of the display as it was the control system because a learning period was necessary irrespective of the control system being evaluated. No additional learning period was required when the control system was changed after the person had been flying the cockpit for an appreciable length of time (10 min. or more).

At one time the scoring system was so changed as to penalize the pilot more for errors made at either the beginning or end of the run than for errors during the remainder of the run. The penalty reduced the scores made, however the scores made with an electric control system were still comparable to those of the mechanical control system. By removing one of the arbitrary disturbing functions, the task became too easy and the scores were too high to allow differentiation between different control system configurations. For this reason, a disturbing function was always used.

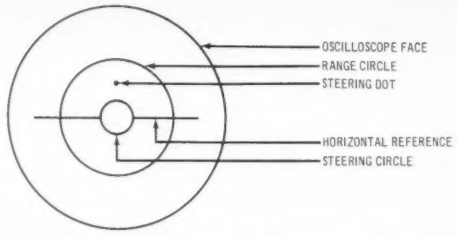

FIG. 4. Scope picture for intercept problem.

STICK CONFIGURATIONS

There are two basic types of sticks which have been proposed and tried with electrical control systems. One is a small formation type of stick which has no mechanical connections to the control surfaces. This stick can provide control to the airplane by electrical signals only although the electrical signals may be developed by either force or displacement transducers. The other basic type of electrical control stick is one which utilizes the mechanical control stick and obtains electrical control signals by suitable force transducers on the stick.

The use of both of these types has proved satisfactory for electrical control, but a problem arises when one considers the effects when the electrical system fails and a pilot is forced to revert to a mechanical system to "bring the airplane home." Again, this would be no problem if the designer were allowed the luxury of two control sticks, one mechanical and one electrical. For this case there would be no argument against the statement that "both systems could be designed separately to give satisfactory flying qualities in each distinctive mode of operation." However, pilots strongly object to changing sticks in time of emergency, and airplanes, in general, cannot stand the weight and cockpit complications involved in installing two sticks. Therefore, it appears more practical to plan to have one stick in the cockpit.

The second type of stick, where a force transducer on the main stick provides the electrical signal, appears to satisfy the one-stick requirement for both modes of operation; however, this type of control has several basic deficiencies for flying in an electrical control mode. The first deficiency is that small surface motions, such as those generated by stability augmentation devices, are also reflected to the stick. This probably would not cause any pilot comment while he is flying in smooth air; however, in rough air the pilot's hand would be in a constant state of agitation which, besides being annoying, has the possibility of exciting a residual oscillation as the mass of the pilot's hand and arm gives signals through the force transducer which would reinforce the oscillations. The use of a series servo, when it is the only servo, does not alleviate this condition for any closed-loop control system, such as the one Convair

is investigating, because the signal which is controlling the airplane is necessarily the same signal used to provide the airplane damping. By using both a series servo and a parallel servo, it is possible to low-pass the input to the series servo and high-pass that to the differential servo, thus obtaining the same overall gain. However, this method uses two servos to solve the problem, and the solution is not considered as desirable as a method using only one servo.

The problem with the normally disconnected stick is how it can be connected to the mechanical control system in time of emergency with a minimum of induced transients. One type of coupling considered would be a clutch type which would connect the stick and the linkage in their relative positions prior to engagement. This type would be the best as far as induced transients are concerned; however, in this case the possibility exists of having the surface hard over in one direction while the stick is hard over in the other direction. This means that the pilot would not be able to correct the airplane's attitude sufficiently to "fly it home" or even to level the plane enough so that he could eject and parachute to safety. The condition used as an illustration is obviously the most critical which could occur although it is entirely possible that enough of a mismatch could occur in clutching which would not allow the pilot enough control to bring the plane back. This implies that a positive centering device is required. There are necessarily problems which come about in the design of a clutching mechanism to accomplish this requirement. If the centering device is made to center positively and fast, it is possible to give both the airplane and the pilot's arm a jolt which would be undesirable.

A possible solution to the objectionable surface feedback to the stick in the force stick method is to develop some form of mechanical low-pass filter which would remove the high-frequency components of the stability augmentation inputs. If this type of filter could be developed, it would appear possible to allow the stick to remain connected at all times. At the present time, this method of electric stick control is considered the most desirable.

Another possibility is to rely entirely on the small formation-type stick. The emergency system would be a separate set of electrically controlled, hydraulic servoactuators that drive the main control valves and position the surfaces proportional to an electrical stick force signal. Part of the weight saved by eliminating cables, bellcranks, stick, mixer, and brackets could be used to provide a separate electrical power source for this system. By keeping the control functions simple, giving extra attention to the routing and mechanical protection of electrical cabling, and using servoactuators with mechanical follow-up instead of electrical feedback, this system could be made extremely reliable. The advantages of the electric rate hold control system could then be fully exploited without mechanical interaction of control surface motion. Both systems could use the same small stick.

Stick Damping

A method to construct a low-pass filter to remove the high-frequency components of surface motion for a force stick has been devised which requires the installation of a viscous damper at the bottom of the stick. This, when coupled with a suitable spring constant in the linkage, would give a low-pass filter to the grip of the stick. The moving cockpit test stand was used to determine the time constant (τ_f) of the filter which could be used. Various values of damping were tried with τ_f varying from 0.1 to 2.0 sec. In the course of these trials, it was discovered that too long a time constant would also produce undesirable results. When the time constant was too long, it required too much time for the stick to start moving after the pilot had initiated a maneuver through the force transducer. It was possible for this condition to exist to such an extent as to be distracting and misleading. If the time constant was too short, it did not remove enough of the high-frequency surface motions. It was found by experimentation that pilots preferred a time constant $\tau_f = 0.3$ to 0.5 sec. while nonpilots flying the cockpit preferred $\tau_f = 0.6$ to 1.0 sec. The introduction of a filter of this type aided only slightly in increasing the evaluating scores over those which were obtained without the filter for the flight conditions investigated. The scores obtained with the filtered control appeared to be the same as those obtained with a disconnected stick.

Reliability Summary

It is believed that the main reason for the reluctance to use electrical control systems in present-day airplanes is that electrical components are relatively unreliable as compared with mechanical components. For this reason, a program to study possible ways to improve the reliability of control system electronic equipment was instigated.

The study was essentially directed toward methods to improve the reliability of circuitry by different arrangements of components. The studies showed that the greatest improvement was obtained when sections were paralleled as much as possible with a monitor for each section and provisions made to remove the parallel portion in case of its failing. It was also concluded that underrating components (from the viewpoint of power) tended to improve the reliability, as did the use of transistors and magnetic amplifiers wherever possible.

One of the systems which evolved from the reliability studies was also simulated on the analog computer. This system is basically the same as the original except that, instead of an elevon position (δ_e), an elevon rate ($\dot{\delta}_e$) is required. This makes possible the utilization of the hydraulic control system as an integrator. The pitch control equation, as previously stated in Fig. 1, is

$$\delta_e/\dot{\theta}_e = K_1 + (K_2/S)$$

This may also be written

$$\delta_e/\dot{\theta}_e = (K_1S + K_2)/S$$

Now, for the purpose of this derivation, it can be assumed that

$$\delta_e \text{ Actual} = [1/(1 + \tau S)]\delta_e \text{ Desired}$$

where τ equals the hydraulic time constant, which for this case was assumed to be 0.06 sec., so

$$\frac{\delta_e}{\dot{\theta}_e} \text{ Actual} = \frac{K_1S + K_2}{S(1 + \tau S)} = \frac{K_2}{S}\frac{(1 + \tau_1 S)}{(1 + \tau S)}$$

where $\tau_1 = K_1/K_2$.

Using the values for K_1, K_2, and τ, the electric stick system reduces to

$$\dot{\delta}_e \text{ Actual}/\dot{\theta}_e = K_2[(1 + 0.3S)/(1 + 0.06S)]$$

which is an easily obtainable transfer function. This method eliminated the need for surface position instruments, an integrating motor, an output transducer, and the associated wiring.

A great deal of apprehension is felt by many people at the thought of removing the electrical surface feedback loop in the full authority electrical control mode. The purpose in proposing this removal for the electric stick system is the great simplification which results. By the simple process of removing the surface feedback and driving the servoactuator with an amplifier, it is possible to use the hydraulic system as the necessary integrator. By this change it is possible to remove two components which may be considered unreliable—the surface feedback transducer and the mechanical integrators. It is felt that, instead of reducing the reliability by this omission, the reliability is considerably increased with no loss of safety or deterioration of flying qualities.

As a direct result of the reliability studies performed, Convair has studied two types of circuit which are considered extremely reliable. Following is an explanation of the advantages and disadvantages of these systems:

(1) One system uses a.c. transducers for both the stick input and the feedback signal. These signals are series-summed and fed into an a.c. transistor amplifier. The output of the amplifier is then summed with the outputs of identical parallel stages into another transistor amplifier which goes into a ring demodulator. The d.c. signal from the demodulator then travels through a passive forming network into the control valve. A diagram illustrating the operation of this unit is shown in Fig. 5. An advantage of this system is that it uses transistor amplifiers throughout, making possible the potting of the complete unit. A disadvantage of this system is the change of system gain if any unit becomes inoperative. In order to maintain constant loop gain, some form of monitoring-switching device (not shown) must be incorporated. Another disadvantage of this circuit is the difficulty with which different signals are summed. In order to sum signals which have different voltage gradients, transformers must be used, and different transformers must be used in order to change the contribution of the different inputs.

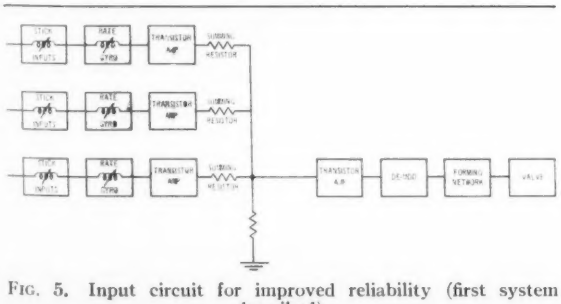

FIG. 5. Input circuit for improved reliability (first system described).

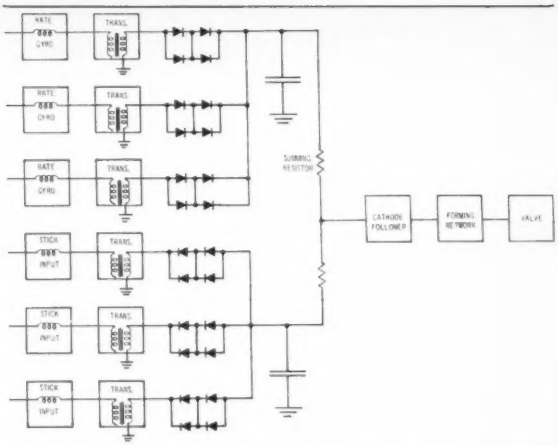

FIG. 6. Input circuit for improved reliability (second system described).

(2) The second system is slightly different in the input stages. The signals from the a.c. stick force transducer and from the a.c. feedback transducer are both biased with a.c. The biased a.c. voltages are then put into a step-up transformer. The output of the transformer is rectified and summed to the grid of a cathode follower stage. From the cathode follower the signal goes into the passive forming network and then into the control valve. A diagrammatic illustration of this system is shown in Fig. 6. The reliability of this system comes from the fact that numerous input stages may be summed, and nothing happens to the system if one stage goes out. The advantages of this system are that, if a combination of feedbacks is used, the ratio of the contributions of each may be changed by merely changing the summing resistors, and the system gain is unchanged if an input to the system goes out. One disadvantage of this system is that a cathode follower is required in order to obtain the high-input impedance which is necessary to sum the inputs effectively. This immediately rules out the possibility of using a transistor or magnetic amplifier stage. Another disadvantage of this system is that of having the feedback gyro stick at zero rate. This would mean that the bias voltage would remain in and there would be no feedback in one direction; however, if a.c. torsion-mounted gyros are used, the possibility of this condition occurring will be small—and in a mechanical linkage failure probability class.

(*Continued on page 77*)

Principles of Self-Contained Navigation

A discussion of the methods and difficulties involved in self-navigation, a field of growing importance.

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The RAND Corporation

Introduction

The relatively unknown field of self-contained air navigation has lately achieved a position of major importance in the aeronautical world, and it is still growing at a tremendous rate. Sufficient proof of the first of these statements lies in the very fact that the IAS devoted a full morning session of the National Summer Meeting to this subject. For further proof, I have dug up a few rough figures on the dollar value of the effort in this field. It turns out that today self-contained navigation is something like a billion-dollar-a-year industry. Furthermore, of that billion dollars, about a third is for research and development, which you all recognize is an exceedingly high percentage by either military or civilian standards. This is the basis for my statement about the tremendous growth rate in this area.

I will now define the term "self-contained" as applied to navigation and then consider briefly the nature of the requirements and the source of the push to improve ourselves in this direction.

By self-contained, I mean simply that all the navigation equipment, all the physical hardware, must be on board the vehicle whose navigation is being considered. With this definition, passive sighting of the ground by visual or infrared or other devices is included, so are celestial observations, and so too is the transmission of radiation to the ground with observation of the reflected energy as in radar. Of course, the ultimate in self-containment is achieved in the pure inertial systems, those modern counterparts of the proverbial windowless black boxes of the old magicians.

The need for self-contained navigation systems is almost entirely military. It is obvious that we cannot allow ourselves to be dependent in time of war on ground-based aids that may be denied us by enemy action—to say nothing of the fact that these same items may aid the enemy as much as or even more than they aid us. By an extension of the same reasoning, our systems must also be jamproof, or at least sufficiently difficult to jam as to force the enemy either to expend a large effort on his jamming or to decide not to bother. This requirement means that external radiations must be utilized with care, if at all, and, again, the pure inertial systems represent the ultimate desideratum.

Increased performance of both civilian and military aircraft in speed, altitude, and range, and the need for an all-weather capability in both cases, all impose additional requirements on the navigation equipment. High speed, in particular, requires rapid and accurate calculations and a convenient presentation of results on a continuous basis that approaches automaticity. Since military aircraft have the highest speeds, in general, they need the highest performance navigation systems. Missiles of course require completely automatic navigation. To repeat, the requirements for increased performance and automaticity, while not solely military, are certainly more stringent in their case than in civilian use, and the requirement for self-contained systems is almost entirely military.

In view of this situation it is to be expected that most of the current work in this field is sponsored by the military services, and that it is classified. Fortunately, people like Eratosthenes, Archimedes, Galileo, Newton, Hertz, Doppler, and their associates all published their findings before the word "classified" even had the meaning it has for most of us today. So I will talk about some of the physical principles that are utilized in various self-contained navigation systems.

Basic Navigation

I like to think of any navigator's job as consisting of two parts: first he must determine where he is, and then he must decide how to get to where he wants to go. He must know (or at least estimate) his present position, and then he must steer so as to reach his destination. The second part of this job, the calculation of steering orders, while far from elementary in a spherical coordinate system and complicated by the existence

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of winds, is nevertheless fairly straightforward. There are further practical problems in the carrying out of even simple steering orders, particularly those involving the vagaries of heading references which usually devolve back onto the navigator. But these are not the problems I wish to talk about this morning.

The primary task of navigation is the determination of present position, and this is our concern today. There are two basically different ways in which this determination of present position can be accomplished. If it is done by means of direct observation of recognizable objects, whether terrestrial or celestial, the process is commonly called "getting a fix." If the position is computed on the basis of a past fix and an integration of velocity or double integration of acceleration since then, the process is called "dead-reckoning." By the way, this word dead does not imply that old-fashioned navigation is a dead art, for it certainly is not. Nor does it refer to the fact that it makes use of past data which are always obsolete and perhaps in this sense dead. The word should really be spelled d-e-d, a contraction of the word deduced. A dead-reckoning or DR position, as it is called, is a deduced—a computed—position, as differentiated from a fix which is directly observed. In practice, all navigation consists of a mixture of fixing and dead-reckoning.

Fixing Methods

Let us look first at the principal methods available for getting a fix. The most basic method of determining one's position on the earth—one's latitude and longitude—consists nowadays of measuring the angles between the zenith and three* or more of the heavenly bodies at a precisely known time. That this small amount of data suffices for determining positions comes about because of two important facts. The first of these is quite fundamental: since the earth is almost spherical, there exists a unique 1:1 correspondence between position on the surface of the earth and the angular orientation of the vertical at each point as seen from outside the earth. (See Fig 1.) Stated oversimply, the verticals all radiate from the center of the earth, each in its own direction, so that every point on the surface can be identified by the direction of its vertical. (The actual nonsphericity and the rotation of the earth are ignored here; they serve to complicate the details of this correspondence, but they do not destroy its existence or in any way vitiate the principle.) The second important fact is a product of civilization. There exists today a very large body of data on the sun and the stars and the motion of the earth with respect to these objects. These data have been reduced, codified, and embodied into almanacs, arbitrarily agreed-to definitions of time, and highly precise chronometers. It is thus possible for a navigator who possesses these aids to know the orientation in space—i.e., with respect to the fixed stars—of, for example, the vertical at the point of origin of latitude and longitude at any time. If he can then measure the orientation of the vertical at his own location—name the star at the upper end of his own plumb bob, so to speak—then simple subtractions will give him his position.

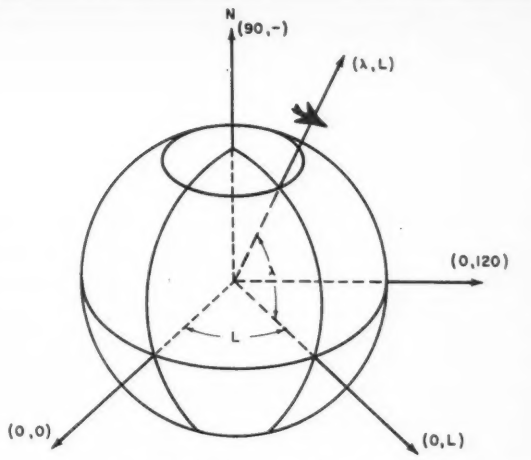

Fig. 1. A schematic diagram of the earth illustrating how positions on the surface can be identified by the orientation of the vertical at each point.

But this measurement of the angle between a star and the vertical is not as easy as it sounds. Angles between physical parts of an instrument can be determined easily enough, and simple telescopes can be pointed at stars, but the physical embodiment of the direction of the vertical, while on board a moving vehicle, runs into an inherent and very basic difficulty. The difficulty is that any device whatsoever, be it plumb bob, or pendulum, or liquid level, or what-have-you, that can respond to the direction of the pull of gravity will always respond equally well, by virtue of its own inertia, to any real accelerations of the vehicle. A more precise statement of this situation will be given later, but for now, a recognition of the following elementary facts will suffice: If a simple plumb bob is hung from a fixed support and no other forces are allowed to operate on the bob, then it will hang in a vertical position; but, if the support is moved horizontally with an acceleration of—say 1/10g—then, ignoring transients, the bob will lag behind making an angle with the vertical whose tangent is 0.1. And so it is that the determination of present position on board a moving vehicle is beset with this fundamental difficulty inherent in any attempt to observe the true direction of the vertical.

As for the accuracies that are obtainable under practical conditions, at fixed stations on the ground (where this fundamental limitation does not exist), it is not uncommon to obtain a vertical that is good to one second of arc—an angle which, if placed at the center of the earth, subtends at the surface an arc length of 100 feet. At sea, one in a sense bypasses the problem

* The use of two stars is adequate if even very rough a priori knowledge of position exists sufficient to resolve the ambiguity of the two points of intersection of the two circular lines-of-position defined by the observations. However, even in this case, three stars are almost always used since the redundant solution permits an evaluation of the errors and a detection of most gross errors.

of the vertical and observes the horizon instead. This has its own limitations, but nevertheless fixes on the high seas are usually accurate to about a mile which corresponds to an error in the vertical of one minute of arc. In the air, the horizon is usually so far away as to be not clearly visible, so the problem of the vertical cannot be avoided. Ordinarily the best that can be done is to average several readings on a bubble or other level indicator. Fixes obtained in this way must be expected to have significantly larger errors than those achievable at sea. A commonly accepted value is of the order of 10 miles,* corresponding to one sixth of a degree error in the vertical. Now a sixth of a degree is just about 3 angular mils, or one part in 344. Following the reasoning given previously, to achieve this kind of vertical requires that horizontal accelerations must be reduced, or at least averaged out, to within 1/344 of a g—an accomplishment not to be sneezed at after all. Even so, you can well imagine that many serious attempts have been made to improve this figure, but short of systems that actually measure vehicle accelerations to better than one thousandth of a g, you can see that such attempts are doomed to failure.

Over land it is of course possible to do very much better than this but only by "cheating"—that is, by looking out the window at recognizable objects and measuring the vector displacement to those objects. When using radar, no vertical at all is actually required, though a crude one is always provided for secondary functions. In these days it is well known that a radar measures distance by timing the round trip of a pulse of electromagnetic energy. The very first energy to return, following a transmitted pulse, must come from the ground directly beneath the aircraft (assuming the terrain is not too rugged), and the returns from other areas are usually spread out on a map-like presentation to assist in the recognition process. In this way, both altitude and slant range to a specified point can be measured directly. The ground range can then be computed by solving a simple right triangle—independent of any errors in the vertical on board. A heading reference is required to convert the ground range to a vector displacement, but an error of 1° here only introduces an error of 1/3 mile when sighting an object 20 miles away, so the requirement for this purpose is not severe. When using visual sighting, only angles can be measured, and this time the vertical is required. Simple trigonometry shows that the error in ground range is given by the product of the error in the vertical, the altitude, and the square of the cosecant of the angle between the horizontal and the line-of-sight. This is far different from the celestial case where the vertical error was multiplied by the radius of the earth. In this optical sighting case, a vertical error of, say 1/2°, when looking down at 45° from an altitude of 30,000 ft., contributes only about 500 ft. to the fix error. These relative fixes by optics and radar certainly have their place. They are mentioned here, however, primarily to emphasize the difference between them and absolute fixes which determine latitude and longitude.

Dead-Reckoning Methods

The simplest air-borne dead-reckoning consists of the following steps: first, true air speed is computed from observations of pitot pressure, static pressure, and outside air temperature; secondly, by assuming no yaw or sideslip, this speed is converted to a vector velocity by reading on a compass (presumably magnetic) the orientation of the nose of the airplane; thirdly, the wind vector, as obtained from a meteorological forecast, is added to the true air-speed vector to obtain the vector velocity of the airplane with respect to the earth; and fourthly, this velocity vector is multiplied by elapsed time to give distance and direction traveled.

All four of these steps, at least as just described, have serious errors, but all four can be improved by the use of various additional devices. For example, if the whole process is mechanized, then continuous integration can replace the multiplication by elapsed time. Also, the use of low-drift directional gyros can reduce the dependence on the earth's magnetic field, our knowledge of which is not all that could be desired. In fact, if an astrocompass can be carried on board and used at intervals to calibrate or zero-set the directional gyro, then dependence on the earth's magnetism can be eliminated entirely. Finally, there are several things that can be done to improve the knowledge of the winds over that provided by forecasts. Simplest of all is the ordinary drift sight. This is nothing more than a telescope in the floor of the aircraft with a rotatable reticle of parallel lines. If the ground is visible, and if this reticle is adjusted so that points on the ground appear to slide by along the parallel lines, then the angle through which the reticle has been turned gives directly the drift angle—defined as the angle between aircraft heading and ground track. This permits the navigator to make good a desired course free from assumptions about yaw, and, when this is combined with the value of true air speed, it is nearly equivalent to a measurement of the cross component of wind. The next refinement is to treat two successive radar or optical fixes separated by a known time interval as a measure of the average ground speed during that interval. This is an important step since it eliminates both the wind forecast errors and the not insignificant errors in the measurement of true air speed. With suitable mechanization, it can be reduced to a fairly simple manual operation. However, it always yields average values which are already out of date as soon as they are obtained due to the fact that the wind itself is continually changing. This effect of wind gradients of course continues to degrade the assumed value of ground speed even more during the longer periods between these wind measurements. Lastly, radars have now been built† which make use of the well-known Doppler principle (a

* See, for example, Locke, A. S., *Guidance*, p. 84; D. Van Nostrand Co., Inc., Princeton, N.J., 1955.

† See, for example Aviation Week, Vol. 66, No. 5, p. 83, February 4, 1957.

principle applicable to all forms of wave motion) to measure directly and continuously the ground speed and drift angle of the aircraft. The important point to make here is that this is the first dead-reckoning system with no inherent limitations—that is to say, given perfect instrumentation of the Doppler radar and the heading reference, this kind of navigation would be exact. Of course there are instrumental errors which we are unable to eliminate, but still Doppler radar provides by far the most accurate dead-reckoning navigation of any that is now in production.

Inertial Navigation

Finally, there is one more distinctly different kind of dead-reckoning, inertial navigation, which will take up the remainder of this paper. I will try to make my description of these systems as physical and nonmathematical as possible, and I will also simplify the situation a great deal by assuming that the earth is a nonrotating sphere and that vehicle motion is limited to horizontal travel in a great circle. Then, once the really basic ideas have been understood, I think you will be able to visualize how some of the complications can be taken care of.

The concepts of inertial navigation can be approached from two directions, but it turns out that the two approaches very quickly merge into one. Although the mechanization and physical construction of inertial systems can take several forms, the basic principles are all the same. One logical approach is to attempt to perform dead-reckoning by doubly integrating vehicle accelerations, but if accelerometers are to measure horizontal accelerations and not be subject to indistinguishable components of gravity, they must be mounted on a gyroscopically stabilized platform that is quite accurately level. Another approach is to attempt to do a kind of continuous celestial fixing in which actual sight lines to stars are replaced by a set of spatial directions provided by gyroscopes which are (theoretically at least) fixed in orientation with respect to the stars. We have already seen that to do this well enough to be interesting requires a determination of the direction of the vertical to an accuracy that can be achieved only if the vehicle accelerations are known precisely. Thus, from either point of view, three things are required: a set of gyroscopes to provide a stable coordinate system, a physical member of some sort that can be maintained accurately vertical, and accelerometers (or equivalent pendulums) to measure vehicle accelerations. The accuracy requirements on these components even turn out to be identical as derived from both approaches. There is just one basic system.

Notice that the measured accelerations are used in two ways. They are integrated twice to yield the distance traveled, and they are further processed by a computer of some sort (as yet unspecified) and used to maintain the "vertical member" vertical so that the accelerometer readings will in fact indicate real accelerations suitable for integration. This is a familiar bootstrap situation, the solution to which lies in a fairly straightforward application of feedback principles.

The whole crux of the matter still lies in establishing and maintaining the vertical member accurately vertical. This problem was first solved in theory in 1923 by a German engineer named Max Schuler.* Although the implementation of his ideas is not easy, his reasoning is actually quite simple and can be paraphrased as follows: Starting with our previous discussion of verticals in connection with celestial navigation, it follows that, when a vehicle is moving over the earth, the vertical associated with its instantaneous position on the earth rotates geocentrically. If the vehicle were moving at a constant velocity, the vertical would rotate at a constant angular velocity about the center of the earth. Any pendulum, for example, located in this vehicle, if initial transients could be avoided or damped out, would rotate with this angular velocity and thus indicate the true vertical continuously. If the vehicle were to accelerate, however, the pendulum would probably lag behind unless it were properly tuned. What Schuler showed was that there is a certain proper frequency such that any pendulum or equivalent device, if tuned to this frequency, would remain vertical even when the vehicle is accelerated.

The physical basis of this statement and the derivation of the proper frequency can be readily demonstrated. Consider a physical pendulum of mass m, length l from pivot to c.g., and moment of inertia mk^2. If the pivot is accelerated horizontally with an acceleration a, the force required must be $F = m\,a$. Due to the inertial reaction of the bob, an equal and opposite force is felt at the bob so that a couple or torque T is applied to the pendulum, given in magnitude by the product of the force and the lever arm, $F\,l$ or $m\,a\,l$. This torque then gives the pendulum an angular acceleration which is found by dividing the torque by the moment of inertia. The angular acceleration comes out to be $m\,a\,l/mk^2$. Now the geocentric angular acceleration of the vertical, to be associated with a linear acceleration a at the earth's surface, is simply a/R, where R is the radius of the earth. The principle of Schuler tuning is then to equate these two angular acclerations—that is, the angular acceleration produced by the inertial reaction torque must be made equal to the proper angular acceleration of the vertical for the moving point. Doing this produces the equation $m\,a\,l/mk^2 = a/R$, whence $k^2/l = R$. Substituting this into the formula for the period of a physical pendulum—namely, $2\pi\sqrt{I/mgl}$—yields the period $2\pi\sqrt{R/g}$, the numerical value of which is a little over 84 min. Such a pendulum is not quite physically realizable as such. However, if the vertical member of our inertial system is designed through servoaction to have this natural period, then, I assert and will prove in a moment, it will behave in every way like a Schuler-tuned pendulum. That is to say, if it is

* See, for example, Wrigley, W., *Schuler Tuning Characteristics in Navigation Instruments*, Navigation, Vol. 2, No. 3, December, 1950.

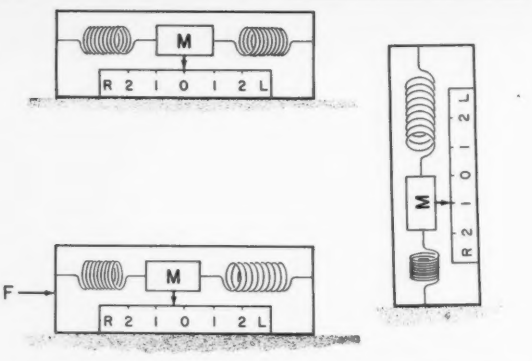

FIG. 2. An idealized accelerometer under several conditions: (*top left*) at rest, (*bottom left*) under the action of an applied force, and (*right*) under the action of gravity and a supporting force when resting on a table in a vertical position.

once properly started (even at rest), it will always indicate the true vertical—except as instrumental errors creep in to degrade the performance; but, if it should ever be displaced, it will oscillate with this 84-min. period.

Returning to our very simple inertial system consisting of gyros, accelerometers, and a vertical element, it is now clear that all that it required, in principle, is to take the computed distance (which was obtained by integrating the accelerometer readings twice), divide this by the radius of the earth (thus obtaining the geocentric angle through which the vertical should be rotated), and then, by means of a servo, mechanically rotate the vertical element through this angle with respect to the fixed gyro reference. The use of a servosystem here really accomplishes two vital things: it makes Schuler tuning possible, and it also permits the gyros to be used in the passive role of sensor, supplying signals but not the energy for vertical member stabilization and rotation. Of course, this must all be done on a continuous basis, and I will presently derive the actual differential equation which the system must follow, but first let me hasten to point out that this simple system, as useful as I hope it is in explaining first principles, is really much too simple actually to work.

What happens in practice is not that anything I have said breaks down, but that the accuracies required to make the system function at all as an inertial system are so high that many complicating factors must also be considered. Most of these complications derive directly or indirectly from the fact that the earth is rotating. For example, in addition to the rotation itself, coriolis accelerations and the elliptical shape of the earth must also be considered. The azimuthal or cross-track behavior of these systems has not even been mentioned. However, we do not have time to go into these, and they are not necessary to a basic understanding, anyway.

I think it is more important to get some feeling for the fantastic component performance that is demanded by these systems. This is, of course, difficult to do on an unclassified basis, but certain obvious requirements can be pointed out. The most obvious, perhaps, comes from the already-mentioned fact that an angle of one minute at the center of the earth covers one mile on the surface, so that errors in the vertical measured in minutes of arc can be translated directly into navigational errors in miles. Another example can be given for gyro drift. According to the second of the two approaches to inertial systems—the one in which the positions of the stars are simply remembered (so to speak) by the gyros—any drift of the gyros will result in an erroneous calculation of present position even if the Schuler pendulum is indicating the correct vertical. Therefore, if the system is to be able to dead-reckon for one hour with an accuracy of one mile, the gyros must not drift more than a minute of arc in an hour. Of course, I cannot say what is actually being achieved, but this very crude and approximate derivation indicates roughly what the requirements are.

THE BASIC DIFFERENTIAL EQUATION

Before closing, I will develop the basic differential equation of all inertial systems. To do this we must look more carefully at just how an accelerometer works. An ideal accelerometer can be visualized as a box containing a mass that it restrained by a spring but is otherwise free to slide on frictionless ways. (See Fig. 2.) If the box is resting in a horizontal position, the mass will be at the equilibrium position for the spring indicating zero acceleration. If the box is pushed to the right, say, with a constant acceleration, the mass will lag behind until the spring is stretched to the point that it exerts on the mass the force just required to give the mass the same acceleration as the box. The mass will then be stationary with respect to the box, and its displacement (to the left) can be read as an indication of the actual acceleration. If the box is now set on a table but turned up on end, the mass will, of course, be pulled by gravity toward the table. If the displacement is read and interpreted just as in the horizontal case, one might conclude that the accelerometer (the box) was being accelerated upward at 1*g*. This is due to the fact that the table is supporting and pushing up on the box with a real measurable force which would produce an upward acceleration of 1*g* if gravity were not also operating. The force of gravity acts on both the box and the mass and so by itself produces no deflection of the spring. Similarly, in an airplane that is being flown at constant altitude, strictly speaking, a vertical accelerometer measures the lift force which is maintained equal and opposite to the force of gravity by devices completely independent of the inertial navigation system. These conclusions are quite general. Any accelerometer measures real accelerations but not gravitational accelerations. The gravitational accelerations must be computed independently and added to the accelerometer readings to obtain the real accelerations with respect to inertial space or the stars. Hence if position is described by a vector $\bar{R}$ from the center of the earth, the total acceleration must be written as

the sum of the nongravitational accelerations $\bar{b}$, measured by accelerometers, and the gravitational acceleration $\bar{g}$, or

$$(d^2/dt^2)\bar{R} = \bar{b}(t) + \bar{g}$$

In the particular case of a spherical and nonrotating earth, the vector $\bar{g}$ is directed toward the center or opposite to the direction of $\bar{R}$, so that the $\bar{g}$ vector is simply $\bar{G}(\bar{R}) = -\omega^2\bar{R}$ where ω^2 is the ratio of the magnitudes of g and R. With this substitution, and writing the operator p for a time derivative, the original equation reduces to

$$(p^2 + \omega^2)\bar{R} = \bar{b}(t)$$

This is the basic differential equation of inertial systems. Most of you will recognize this equation as that of an oscillatory system whose natural frequency is $\omega = \sqrt{g/R}$ and whose period is therefore $2\pi\sqrt{R/g} = 84.4$ min. This system is then acted upon by a forcing function, the observed acceleration $b(t)$, and the problem is to find R as a function of time. With perfect instrumentation and perfect initial conditions, the solution can be exact. A simplified block diagram of a one-dimensional system that would solve this basic differential equation is depicted herewith (Fig. 3).

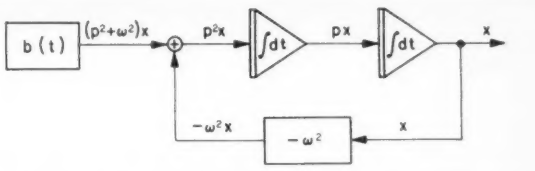

FIG. 3. Block diagram of a simple inertial system in one dimension.

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A discussion of the importance and type of aeromedical investigation in determining the cause of aircraft accidents.

Aeromedical Investigation of Aircraft Accidents

Col. H. G. Moseley,* USAF (MC)

THE PHYSICIAN who is confronted with an aircraft accident investigation is faced with an unusual diagnostic problem. It is a problem of identifying the cause of injuries which may have been inflicted, and it is a problem of finding the reasons for this unwelcome visitation of disaster.

The importance of the aeromedical investigation should not be depreciated. An aircraft accident is a circumstance often attended with harm or death to the human occupants. Alleviation of these traumatic effects must be based upon inquiry into cause and effect. In those accidents where the enormity of force overwhelms any protective effort, there is a responsibility for determining the cause of the disaster itself in order that it may not be repeated. When the reason for such death and destruction lies within the frailty of human physiology or aberrations of human behavior, the professional obligation to identify such causes is as great as the obligation to identify the source of a virulent epidemic. Only upon such observations can true remedial action be taken.

The medical investigation to engage these problems falls into two categories—inquiry into the cause of injury and inquiry into the human factors which may have caused the accident.

CAUSE OF INJURY

Ordinarily this phase of inquiry is first pursued. In a typical accident, many areas need to be explored.

The immediate concern of any physician attending an accident is giving professional aid to those who may be injured. Therefore, the first action is to determine the nature and extent of such injury in order that treatment may be given where most needed. However, beyond the need for knowing what treatment must be given, there is need to know many details concerning the injury, whether it be serious or trivial, for the injuries sustained are the most fundamental of all exhibits concerning the malevolence of the accident. Only from this evidence can the injurious forces and objects be measured or traced. All too frequently, descriptions of injuries are so casual that it is subsequently impossible to determine the direction of the blow which caused a skull fracture or to identify the objects which caused death. In this respect, there is a professional obligation not only to attend the injured but to observe all lesions carefully in order that they may be correlated with the cause and such causes subsequently eliminated.

Coincident with appraisal of injuries, it is necessary to know whether or not such injuries were inevitable under the circumstances encountered, or whether they were compounded by inadequate provisions for escape and survival. Many burn injuries would not have occurred had reliable escape mechanisms been provided, and many sprains and fractures have resulted because escape hatches or exits were so situated that injury was almost inevitable if they were used. All such observations form a basis for remedial action. In connection with military accidents, injuries incurred in connection with bailouts and ejections need also be evaluated.

Directly correlated with injury are the forces to which the occupant is subjected. It is apparent that, when extremely high or explosive deceleration forces are encountered, the human structure cannot withstand the trauma regardless of protection offered. However, frequently there is injury even though the impact forces were slight or moderate. In these cases, there is an indictment against protective equipment. Without knowing or estimating the force and direction of such force, it is difficult to determine whether or not structural improvements should be made. A large number of vertebral fractures occurred in crash landings of jet aircraft before it became apparent that the slap-down force of impact was causing the occupant to sink deep into the seat cushion which negated the restraint of his shoulder harness and allowed him to jack-knife forward over the lap belt. It was only when aeromedical observations on the magnitude and force of deceleration were made that this cause was discovered and subsequently alleviated by providing more resistant seat cushions.

The majority of injuries incurred in aircraft accidents are either due to the occupant being thrown upon impact or due to inadequate restraint of head or extrem-

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* Chief, Aero Medical Safety Division, Directorate of Flight Safety Research, Norton Air Force Base, Calif.

ities with their resultant flailing during abrupt deceleration. There are very fundamental observations to be made in these areas. The first has to do with the effectiveness of torso restraint. In this respect, it is important to determine whether or not lap belts failed, seats failed, seat attachments failed, floors failed, or any other restraint or linkage did not meet the requirement of preventing the occupant from becoming a missile. An additional aspect of this investigation is to determine whether or not adequate protection was provided against flailing of the head or extremities. Even though the torso is restrained, unfixed appendages may be whipped about and injured.

The traumatic role of hurled objects needs inquiry. Even though the individual is adequately restrained and in seats which face rearward to prevent flailing or whiplash injury, serious or lethal blows can be caused by flying baggage, tool boxes, and other objects. Insofar as possible, these need to be identified in order that their traumatic role may be recognized and corrective action taken.

In addition to missiles, fixed structures often inflict injury. This may occur even in low-impact accidents because of the obtrusive or unyielding nature of such items as gunsights, knobs, or metal bars on seat backs. When such items are identified, much can be done to eliminate them in future design.

Any other cause of death or injury needs to be traced to its source and conclusions drawn as to what could be done to prevent it. The most frequent injuries not directly due to deceleration are burns. Upon medical burn observations, the USAF has been instrumental in developing more resistant clothing and establishing the requirement to wear gloves. Much additional remedial action needs to be taken to eliminate the source of such burns, and no inquiry in this area is too trivial.

Human Factors as Cause of the Accident

When the medical investigator attempts to determine whether or not pilot error may have contributed to or caused the accident, he is confronted with a formidable problem. In the aircraft wreckage, there are no fragments of behavior or atmospheric vacuums that serve as tangible evidence of acts or omissions which may have precipitated the course of events which ended in the accident. However, by working with other investigators, definite conditions concerning the flight and the aircraft itself can be established. Upon these observations, it frequently becomes apparent that some unsafe act on the part of the pilot (or crew) led to the mishap. The reason why, then, becomes a matter of concern. Here it is essential to realize that pilot error does not of necessity imply neglect or fault on the pilot's part. On the other hand, such error may be the result of circumstances with which he was physically or physiologically ill-fitted to cope or as a result of problems which he had not yet learned to solve. The medical inquiry, therefore, can follow the influences which have the most significant effect on the human operator. There are three major areas where adversities or inadequacies may induce the pilot to err and lead to an accident: the pilot's physiological tolerances, the pilot's behavioral variances, and the pilot's physical condition.

First consider the pilot's *physiological tolerances.* Man's basic physiology has prepared him to live in the dense warm atmosphere adjacent to the earth's surface and to gain his orientations by firm contact with the earth's surface. High altitudes, high velocities, and space are entirely alien to his instincts and enormouslv hostile to his physiological equanimity. In fact, man survives in high performance flight only by the preservation of an artificial environment which guarantees him adequate oxygen, heat, and comfort and by instruments and cues which inform him of his orientation or direction in space. When anything goes wrong or disturbs this environment or orientation, he is quickly overwhelmed. The resultant accident is usually the type where the aircraft plunges to the earth with little or no effective human guidance. These are vertical disasters. Whenever the investigation reveals this type of accident, the overwhelmed pilot must be considered. In the wreckage, mechanical cues are few or nonexistent. Only rarely is there evidence of improper pressurization or oxygenation. Still more rarely are there cues of noxious fumes or malfunction of gyros or attitude instruments. However, whenever an aircraft accident cannot be explained by other reasons and when it is of the vertical disaster type, the causes that follow should be considered.

Hypoxia: If the accident is the result of a power-on dive from high altitude with no apparent attempt to correct its course or to escape, and especially if it occurs on a clear day or night, hypoxia can be considered as the most probable cause. With the exception of disorientation as mentioned below, there are few if any other conditions currently encountered in flight which can so suddenly and so completely overwhelm the pilot.

Disorientation: Whenever there are power-on dives when the aircraft is being flown under instrument conditions and particularly when there is evidence that the pilot's attention has been diverted from his flight instruments or if he has had to make the transition suddenly from outside visual reference to instruments, disorientation is a highly probable cause. This is particularly true if the dives are from low altitude flight such as in the traffic pattern; however, this type of phenomenon knows no altitude limitations.

Other Adversities: Whenever flight becomes erratic and there is no mechanical or other explanation, incapacitation from other environmental adversities must be considered. These are such conditions as decompression sickness, poisoning by effects of carbon monoxide or noxious fumes, extreme heat or cold, and allied conditions which might seriously compromise the pilot's ability to handle the aircraft. This category is seldom encountered and is difficult to identify. It is usually implicated only when the pilot has indicated such conditions by radio calls or when the accident investigation reveals loss of pressurization, noxious substances, etc.

The area concerned with the pilot's *behavioral variances* warrants consideration. Abnormal behavior is seldom the cause of an accident. Individuals who develop a psychosis or severe psychoneurosis are usually removed from flying. Individuals who do not have the mental capacity to handle an aircraft seldom become pilots. However, many pilot error accidents occur as a result of normal human variables such as inexperience, oversights, apprehensions, and distractions. These accidents are almost always characterized by evidence of conscious control of the aircraft prior to the accident and thus lead to what may be termed horizontal disasters. In these cases, the pilot is flying straight and level or he is coming in for a landing or he is engaged in a take-off when, as a result of some inadequacy, the accident occurs. Whenever an accident cannot be explained by other reasons and it is of the horizontal disaster type, certain factors should be considered.

Discipline Delinquencies: Modern flying, and particularly flying high performance aircraft, requires rigid adherence to certain basic precautions and rules. Poor flight planning and poor in-flight discipline—i.e., attempting to fly VFR under IFR conditions—are the most frequent causes of in-flight collisions. To this must be added poor supervision, particularly in flight scheduling, which can lead to mid-air collisions. These poor disciplines should always be considered when controlled flight ends in a collision.

Inexperience: Accidents as a result of mishandling the aircraft upon landing, take-off, or go-around and particularly accidents as a result of mishandling of landing gears, flaps, or fuel systems are usually due to inattention or inexperience, especially the latter. Such accidents are usually of low impact, and survival is the rule. Evidence of the type of mishandling such as failure to put the wheels down is frequent. The aeromedical role is to determine the reasons for omissions or mishandling. Even though inexperience is a nonclinical condition, it can, nevertheless, lead to disastrous results and is fully deserving of identification when it is the cause.

Complications and Distractions: During landings, take-offs, and go-arounds, the work load placed upon the pilot is considerable. If during this time, minor irregularities or emergencies arise, he may become overwhelmed and have an accident. Here again, there is a necessity for identifying such complications and distractions in order that they may be eliminated.

Finally we come to the pilot's *physical condition*. Flying requires that the pilot have certain minimums of physical strength and endurance and that he be physically able to give continuous application to his occupation during the expected conditions of flight. Occasionally, pilots are unable to meet these physical requirements due to fatigue, illness, or physical disaster. Such inadequacies or unwelcome infirmities are usually unpredictable, and there is no particular pattern as to the type of accident which may result. In addition, such accidents usually leave no mechanical clues as to their cause. Their discovery rests upon exclusion of other causes, and inquiry into definite areas.

Insufficient Strength or Stamina: Although inability to reach controls or insufficient strength occasionally leads to accidents, the most frequent cause in this category is fatigue. Whenever accidents occur after prolonged periods of flight, are due to some omission or mishandling, and cannot be explained by inexperience or other factors, fatigue is implicated. Although difficult to establish, it may emerge as the only plausible explanation.

Temporary Illness: This is an infrequent cause of accidents because the ill pilot seldom flies. There are two factors, however, which need to be considered whenever it can be determined that the pilot was suffering from a temporary illness. The first is whether or not he may have developed severely diverting symptoms from such conditions as headaches, earaches, or sinusitis, and whether or not he may have been taking medicines with suppressive or hypnotic effects or an anaphylactic potential.

Serious Physical Incapacitation. Serious incapacitation may arise suddenly and lead to an accident. Such conditions as heart attacks are rare and are ordinarily discovered only by careful post-mortem inquiry. However, accidents occasionally happen because of other serious conditions, such as epilepsy, and offer little or no pathological evidence. Their discovery rests in a careful review of the individual's medical history and particularly inquiry into concealed attempts at self medication.

Conclusions

The aeromedical investigation of an aircraft accident is concerned with discovering the causes of injury and determining the human acts which may have led to the accident.

The investigation of injury requires careful inquiry into cause and effect and detailed examination of forces and objects which produce injury. It also requires review of protective devices which prevented or failed to prevent injury.

Investigation of human error which may have led to the accident, and the cause of such error, is also required. This entails an evaluation of adverse physical or physiological influences, a full appraisal of the pilot's clinical history, and, on occasion, careful pathological inquiry.

The need for thoroughness of such inquiry is great. The causes of aircraft accident injuries and particularly the human causes of the accident itself are frequently difficult to establish. But only when such causes are found can effective corrective action be taken.

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Rocket Sled Techniques (Continued from page 62)

braking device undertakes the task of bringing the sled to a stop. During the coast phase, electrical power to the high-speed cameras and telemetering equipment is shut off in order to conserve the batteries, prevent film damage, and avoid the necessity of having personnel approach the sled immediately after the run. This last item is a safety precaution against the possibility that one or more of the rocket motors may have misfired.

It is apparent from the above discussion that one of the most important elements of a rocket sled flutter test is the method by which the sled performance is estimated. The analysis is used not only to predict the maximum speed and allow for variations in weather conditions but also to enable a determination of the range stations at which the successive rocket stages must be fired along with the number and size of the rocket motors to be used in each stage. In attempting to maintain reasonable and precise speed increments from one run to the next, this process may become quite involved and may require the use of such practices as overlapping or delaying the firing of two stages or the addition of dead weight to the main or booster sleds. The method must be applicable to a wide variety of configurations and should be capable of utilizing the results of past runs with a minimum calculation time.

Conclusions

By virtue of the increased attention which the flutter problem demands in the design of high-speed aircraft, there has come a need for full-scale flutter testing. Such tests are intended to prove the validity of the design analysis and serve to establish with finality the actual flutter margin of safety. The rocket sled method qualifies uniquely for this purpose through its ability to reproduce and exceed actual flight conditions.

Instrumentation and test procedures have been recently developed and successfully employed in full-scale rocket sled flutter testing. The results of these tests have established beyond doubt the usefulness and validity of the rocket sled technique as a part of the basic design process for future transonic and supersonic aircraft.

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Electrical Flight-Control System (Continued from page 67)

Both systems are capable of being potted to prevent wire breakage or vibration damage, and each anticipates the use of quads wherever they will improve the reliability, as shown with the diodes in Fig. 6. Attempts are being made to overcome the necessity of using a vacuum tube for a cathode follower which is the primary disadvantage of the second system. Methods to correct this include use of ceramic tubes and methods of operating tubes in parallel such that, if one tube fails, the other will continue operating. At the present time there are differences of opinion as to which system may be made the most reliable for use in aircraft. A decision could easily be made if component reliability values were dependable and accessible. Either method can be proved more dependable, depending upon which component reliability values are used. Consequently, the tests and analyses on both systems are continuing.

From the results of this development program, it appears that electrical control systems are not impractical to consider for future airplanes. When one considers that most advanced aircraft are being designed with some type of automatic control, such as stability augmentation, automatic navigation, or automatic interception, it begins to appear quite logical that the manual control mode should also be electrical. This would mean that, for the addition of a few electrical components, the pilot could be given desirable manual flight characteristics with a lighter, more flexible system that can be provided mechanically.

Reliability of electrical control systems has been improved considerably thus far, and efforts are continuing. At such time that the reliability of electrical control systems can be made to equal that of mechanical systems, it is firmly believed that all high-performance aircraft will be "flying by wires."

News of Members (Continued from page 35)

Harold W. Thomas (AF), formerly Military Sales Representative, Lockheed Aircraft Corporation, has been appointed Manager, Industrial Department, Project Development Division, The Ralph M. Parsons Company.

T. H. Townsend, Jr. (M), formerly a Senior Aerodynamicist, Lockheed Aircraft Corporation's Georgia Division, has joined Temco Aircraft Corporation as a Technical Specialist in Aerodynamics.

John R. Westfall (AF), formerly Executive Engineer, Dynamic Loads Division, NACA, Langley, is Laboratory Administrative Engineer, McDonnell Aircraft Corporation, St. Louis, Mo.

Fred A. Winzer, Jr. (M), former General Sales Manager, The Weatherhead Company, is Vice-President—Sales, Waldorf Instrument Company, Huntington Station, Long Island, N.Y.

CORPORATE MEMBER NEWS

• **Aerojet-General Corporation** has announced the following appointments: Thomas E. Johnston, General Purchasing Agent; Harvey S. Fisher, member of the Materiel Staff; and Richard E. Minnick, Head, Materiel Operations Department.

• **Aeroquip Corporation** has announced the appointment of Allan B. Fredhold, Jr., as General Manager of General Logistics, the firm's subsidiary.

• **Aircraft Radio Corporation** has announced publication of brochure ARCBR-T20-1, describing the firm's new "building block" 20-channel VHF Transmitter (Type T-20).

• **Aluminum Company of America** has announced two new high-temperature soldering materials that, the firm says, will cut joining costs for aluminum fabricators. Designation for the new materials is Alcoa Solder No. 805 and Alcoa Soldering Flux No. 66. . . . The firm also has announced that it has whirled a precision-cast high-speed aluminum impeller at just under three times the speed of sound. Alcoa scientists said that they tested the premium strength aluminum-alloy casting at a peripheral velocity of approximately 2,000 m.p.h.

• **American Airlines, Inc.,** Board of Directors has elected F. C. Wiser Assistant Vice-President in the Operations Department. W. Braddock Hickman has been elected Assistant Vice-President, Economic Research.

• **Anderson, Greenwood & Co.** has modified its Mach 4 ram-jet test stand to permit evaluation of free spinning test models, as well as those which are statically mounted. The firm reports that the performance of ram-jet power plants, rotating at angular velocities up to 30,000 r.p.m., can be investigated at sea-level atmospheric conditions for flight Mach Numbers as high as 4. Also, these test environments can be maintained intermittently for duration of up to 5 sec. The facility also is utilized as a wind tunnel for heat-transfer studies.

• **Bell Aircraft Corporation** has announced the appointment of Peter J. Wacks as Assistant to the President for Industrial Relations.

• **Bendix Aviation Corporation** has announced the appointment of Charles D. Manhart to the new position of Staff Directory, Military and Government Sales . . . . Eclipse-Pioneer Division's PB-20B automatic flight control unit is reportedly the first commercial all-transitorized control system in commercial use. It was designed as an integral part of Lockheed 1649A Starliners.

• **Boeing Airplane Company** has announced a new facility for testing the firm's jet-engine sound suppressor-thrust reverser unit that will be built at its Transport Division plant at Renton, Wash. . . . George S. Schairer has been named Director of Research . . . . Facts and figures on Boeing's 707 transport have been published in a new booklet by the Transport Division.

• **Chance Vought Aircraft, Incorporated,** reports carrier take-off and landing techniques for the firm's F8U-1 Crusader have been developed aboard the "Franklin D. Roosevelt."

The IM-99 Bomarc interceptor missile hurtles into the air at the USAF Missile Test Center at Patrick Air Force Base. Boeing Airplane Co., the manufacturer, reports it has a range greater than any other current air defense missile. After the booster rocket burns out, two Marquardt ram-jet engines in the body take over.

• **Cornell Aeronautical Laboratory, Inc.,** has announced the appointment of Clifford C. Furnas (F), Chancellor, University of Buffalo; and Walker L. Cisler, President, Detroit Edison Company, to the Board of Directors.

• **Douglas Aircraft Company, Inc.,** engineers are conducting experiments to find the most effective means of suppressing jet-engine noise by "blowing smoke rings." The rings or smoke slices permit visual reference for correlating geometric properties of the exhaust with the sound produced.

• **Fairchild Camera and Instrument Corporation** has announced the election of Edward Streeter as a Director of the firm.

• **Fairchild Engine and Airplane Corporation,** Guided Missiles Division, has established a new Development Planning Staff, headed by Harry Iddings, to undertake programs of study and analysis of new missile systems and electronic techniques . . . . The Engine Division has announced the appointment of Arthur L. Armantrout as Director of Industrial Relations.

• **Federal Telecommunication Laboratories, Division of International Telephone and Telegraph Corporation,** has announced that it is supplying the guidance system for the Army's Lacrosse missile. . . . The firm's two multiengined aircraft which compose its air wing have been moved from Westchester County Airport to a new location near Nutley, N.J. . . . Charles W. Vadersen has been named Manager, Coordinated Telephone Projects.

• **The Firestone Tire & Rubber Company** has announced a new line of airplane tires incorporating features developed and tested on military jets. The new tires are available to civilian light plane owners. . . . Firestone's Defense Research Division engineering laboratory will develop and test components of the new Martin Matador TM-61 B.

• **Flight Refueling, Inc.,** has announced the appointment of James J. Wilder as General Manager of the firm's subsidiary, Automation Industries, Inc., and Charles J. Mozley as Staff Counsel.

• **The Garrett Corporation's** DC-3 "Green Hornet" has been modified to provide what the firm calls "the greatest visibility of any airliner in the world." The Aviation Service Division has installed an extra 1,200 sq.in. of glass above the pilots' compartment . . . . AiResearch Manufacturing Co. of Arizona reports improved efficiency and savings in time and money in aircraft ice and snow removal through new application of a small gas-turbine engine. Hot air is bled from an AiResearch GTC 85 turbine compressor and, used in conjunction with a Pitman hydraulic lift, is directed onto iced surfaces by a nozzle. This division also reports expansion of electronic and pneumatic control facilities in Phoenix. . . . AiResearch Manufacturing Division engineers have developed an all-stainless steel welded and brazed heat exchanger for commercial aircraft that will be produced for the Douglas DC-8.

MISSILE SYSTEMS AERODYNAMICS

Weapon systems management activities at Lockheed's Palo Alto, Sunnyvale and Van Nuys organizations call for major achievement in aerodynamic areas such as: Theoretical and experimental investigations of the aerodynamic characteristics of missiles at Mach numbers through the hypersonic range; optimization of controlled missile performance; specification and supervision of experimental aerodynamic investigations required to verify and improve missile and weapon system design; analysis and interpretation of aerodynamic flight test data. Inquiries are invited. Please address the Research and Development Staff, Sunnyvale 21, or Van Nuys 15, California.

Here members of the Aerothermodynamics Staff discuss heating of jet control surfaces. Left to right: W. E. Brandt, thermodynamic analysis; M. Tucker, Aerothermodynamics Department head; R. L. Nelson, project aerodynamics; B. W. Marsh, aerodynamics; J. I. Osborne (back to camera), aerodynamics.

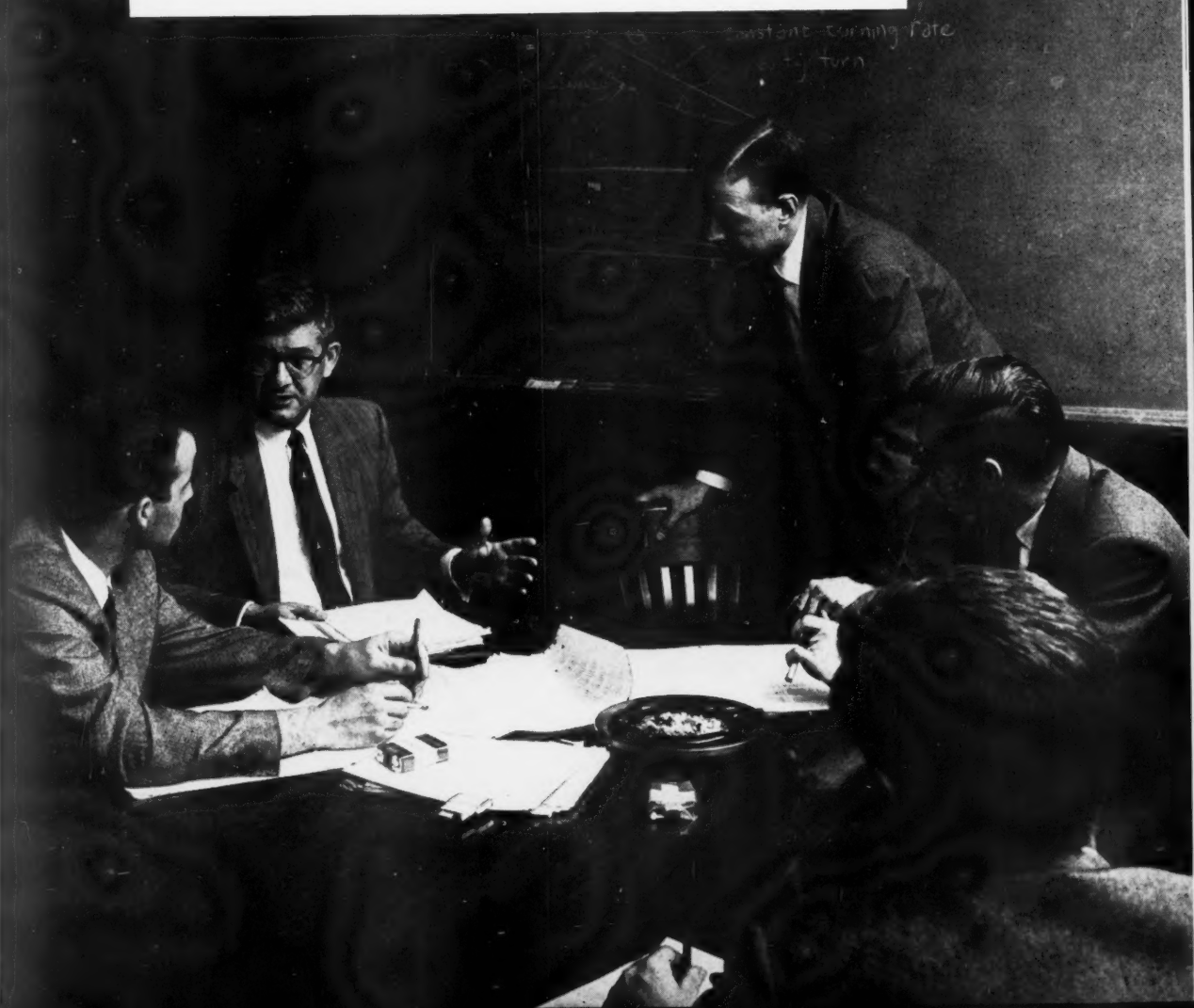
Lockheed

MISSILE SYSTEMS DIVISION

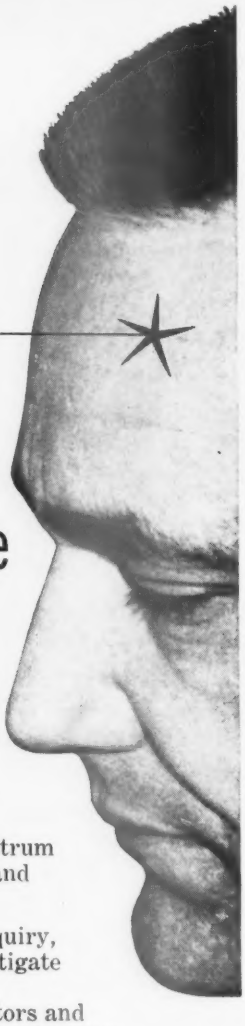
LOCKHEED AIRCRAFT CORPORATION

PALO ALTO • SUNNYVALE • VAN NUYS

CALIFORNIA



Research Engineers



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Marquardt Aircraft, the leader in ramjets—"Powerplant of the Future"—offers research engineers a veritable spectrum of advanced projects; advanced in time, and in technological significance.

In an environment which permits free inquiry, Marquardt engineers and scientists investigate many aspects of supersonic propulsion; including ramjet, turbojet and rocket motors and Aircraft Nuclear Propulsion. This work is achieving a new understanding of the aerodynamic, thermodynamic, and chemical behavior of various elements of these propulsion systems and their exotic fuels.

In other areas, such as the broad field of New Products Research, Marquardt engineers investigate projects reaching far into the future. In keeping with the company's reputation for products which are in the forefront of advancing technology, these projects are timed for tomorrow.

Research engineers with creative vision are invited to investigate the opportunities at Marquardt. Please write Jim Dale, Professional Personnel, 16553 Saticoy Street, Van Nuys, California.

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VAN NUYS, CALIFORNIA — OGDEN, UTAH

FIRST IN RAMJETS

• **General Dynamics Corporation,** Convair-Astronautics Division, has announced development of a "computer-converter" named Addaverter—a machine the division claims "speaks" in both analog and digital terms—to help simulate and evaluate ICBM performance . . . . Convair in San Diego has announced design of a new aircraft door for the 880 jet transport. Forward and aft entrances will be equipped with a new outward-opening, sedge-shaped, plug-type door. The division reports that excavation for a Cyril Bath stretch press has been completed and that a new facility for adhesive bonding of integral wing fuel tanks for the 880 is under construction . . . . Convair in Fort Worth is replacing wooden shipping boxes with less expensive steel crates which may be used indefinitely. The crates are said to be lighter than the wooden boxes, provide more protection, and can be tailor-made to any size. They work along lines similar to a child's erector set.

• **General Electric Company,** Aircraft Gas Turbine Division, unveiled a full-scale model of its CJ-805 commercial jet engine in Paris. Counterpart of the military J-79, it will be available in five versions tailored to specific air-line operational route structures. The division's Small Aircraft Engine Department has announced completion of 3,500 hours of testing of its T58 gas turbine. This department also announced construction of a new furnace facility for treating jet-engine components . . . . Defense Electronics Division, Light Military Electronic Equipment Department, has named Oliver H. Winn, Manager—Engineering and Harry F. Mayer, Manager—Advanced Electronics Center . . . . Apparatus Sales Division, Aircraft Accessory Turbine Department, has announced a new fully self-contained electric and hydraulic auxiliary power unit for missiles and an improved electronic leak detector said to be so sensitive it can detect one part of helium in two million parts of air. The division's Instrument Department is offering eleven free courses in aircraft instrumentation at the Technical Training School, West Lynn, Mass. Welding Department engineers have developed two new Fillerarc welding power sources for consumable electrodes gas shielded welding.

• **General Precision Equipment Corporation's** subsidiary, General Precision Laboratory Incorporated, has opened a 23,200 sq.ft. environmental test building on its Pleasantville, N.Y., facility.

• **G. M. Giannini & Co., Inc.,** has developed a new line of axial accelerometers said to feature extremely low crosstalk (0.01 g/g max.) and low threshold. Giannini engineers also have developed a shaft position transmitter which they say has infinite resolution and null point at the center of rotation and is highly accurate.

• **The B. F. Goodrich Company** has developed a new jet aircraft tire said to be cooler-running and to survive up to three times as many high-speed take-offs and landings as conventional tires used on jets. The tire's improved performance is laid to a ventilated tread design called "Sine-wave." The firm also announced plans for construction of a specialized plant for manufacture of adhesives.

YOU CAN EXPECT MORE FROM BENDIX RED BANK DC GENERATOR SYSTEMS

AIRCRAFT ENGINE-DRIVEN D. C. GENERATORS FOR 30-VOLT SYSTEMS

Type No.	Nominal Rating			Approx. Wt.—Lbs.	Des'd to Gov't Spec.
	Amps.	Speed Range RPM	Altitude Feet		
30E01	50	2200-4500	20,000	24	M-2, M-3
30E22	50	4000-8500	50,000	16	—
30B24	50	4000-8500	50,000	14	—
30E16	100	2500-4500	50,000	40	52B6588
30B33*	100	4700-8000	35,000	28	MIL-S-9181
30E07	200	3350-8000	50,000	45	AN-3632
30E20	200—Class C 300—Class A	4000-8000	65,000	45	MA-1
30E02	300	3450-8500	25,000†	64	—
30B37	300—Class C 400—Class A	4000-8000	65,000	53	—
30E10	400	3100-8000	60,000	67	AN-3624
30B34	400	3100-8000	60,000	67	—
30B26	400—Class C 500—Class A	4000-8000	65,000	69	MA-11
30B35*	400—Class C 500—Class A	3500-8000	65,000	75	—

*These units are Starter-Generators. †Models also available for operation at 50,000 ft.

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Export Sales and Service: Bendix International Division, 205 E. 42nd St., New York 17, N.Y.

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Bendix AVIATION CORPORATION

A thousand products— a million ideas

• **The Goodyear Tire & Rubber Company, Inc.,** has announced that it is supplying Tri-Metallic disc brakes and cast wheels for the Fairchild F-27 Friendship.

• **Jack & Heintz, Inc.,** has announced the election of Chester A. Thompson to the board to fill the vacancy created by the resignation of Rodney P. Lien.

• **Lear, Incorporated,** reports its LearCal and Grand Rapids Divisions are supplying air-borne electronic intelligence components that control and direct the Boeing Bomarc IM-99 missile . . . . Grand Rapids Division has developed a remote control system for vehicles for use in obtaining data from remote, hazardous, or otherwise inaccessible areas via a television transmitter. The Marine Corps has tested the unit on landing vehicles during dangerous surf conditions. . . . LearCal Division engineers have designed a new type of gyro drift recorder (Model 2249) that they say is capable of detecting, indicating, and recording with extreme accuracy the minute increments of drift characteristic of modern high-precision gyros . . . . Lear-Romec Division is manufacturing a heavy-duty 24-vdc electric motor driven industrial coolant or transfer pump. The division says it is designed to pump water or a mixture of water, butyl alcohol, and ethylene glycol in heat exchangers or large equipment. Designated Model RG16070, it has a rating of 400 g.p.h. (minimum) with 14 to 16 psia inlet pressure and a 15 psig discharge pressure, according to the division.

• **Lockheed Aircraft Corporation's** Georgia Division announced that it has been allocated funds by the USAF Air Materiel Command to complete basic units of an advanced nuclear research and development laboratory for use in connection with the firm's nuclear-powered aircraft program. The division also has announced the promotion of B. A. Martin from Chief Pilot to Weapons System 125A Manager. Lloyd W. Harris succeeds Martin as Chief Pilot. The division reports the first B-47 Stratojet to be overhauled under the Modification-IRAN (Inspect and Repair as Necessary) contract has been received . . . . California

Norden-Ketay Corporation's new miniaturized floated rate gyro (Model 55,000) was designed expressly to meet rugged environmental conditions encountered in missiles, according to the firm. It can be supplied in a variety of maximum rate ranges from 1 deg./sec. to 1,000 deg./sec., and the firm reports it has a higher power signal output than has been previously available.

Division has announced a series of executive changes headed by the appointment of Herb Caldwell as Assistant General Manager, Navy Projects . . . . J. B. Wassall, Director of division engineering, has announced that the Navy P2V-7 Neptunes are being equipped with turret-mounted 20-mm. cannons, replacing .50-caliber machine guns . . . . Rear Adm. Joseph F. Quilter, USN (Ret.), has joined the staff of the Missile Systems Division Product Planning Branch . . . . Four Allison 501 prop-jet engines have been installed on a Super Constellation for advance proving of the engine-propeller combination for the Electra.

• **Marquardt Aircraft Company** has announced the appointment of James F. Stengel to the position of Director of Industrial Relations.

• **The Martin Company** and the Navy have announced a new air-to-surface missile, the Bullpup, designed to be launched from any position outside the effective range of enemy high-volume ground fire and said to provide sufficient accuracy to destroy small targets without excessive sorties and expenditures of bombs and rockets. Approximately 11 ft. long, it weighs about 600 lbs. . . . The firm also reports that a new low-cost portable jet-engine muffler, designed to reduce noise of jets on military and civilian airports, has been developed.

• **Meletron Corporation** has announced the election of Volney P. Morin to Executive Vice-President and William A. Clegern to Vice-President in charge of Product Development. Mr. Morin was formerly Resident Counsel for Technicolor Corporation. Mr. Clegern had been Manager—Marketing at General Electric Company's Jet Engine Division.

• **Norden-Ketay Corporation** has announced the appointment of Francis P. Halas as Midwest Regional Sales Manager.

• **North American Aviation, Inc.,** has announced the use of television cameras to observe static test firings of high-thrust, liquid-propellant rocket engines at the Rocketdyne Division's Propulsion Field Laboratory.

• **Northrop Aircraft, Inc.,** has announced its SNARK SM-62 missile was displayed among NATO exhibits at the Paris Air Show.

• **Pan American World Airways, Inc.,** and Panagra have announced a new 30-day excursion fare to Buenos Aires . . . . Wendell R. Stevens has been named to the newly created position of Cargo Sales Manager . . . . Latin American Division has announced that seven specialists are being sent to Afghanistan and Turkey in conjunction with technical assistance projects operated in cooperation with the Government. The division also announced the addition of Bridgetown, Barbados, to its Caribbean route stops.

• **Phillips Petroleum Company** has been awarded an Air Force Scroll of Appreciation for outstanding service to the USAF in the field of solid propellant rocketry from 1951 to the present. The scroll was presented by Major Gen. John W. Sessums, Jr., ARDC Vice-Commander.

• **Piasecki Aircraft Corporation** has announced that it has an option to manufacture the Fairey Ultra-Light jet, to be known as the Piasecki Model 72, for marketing in this country. The two-seat, jet-powered, single rotor aircraft, said to be the world's smallest, is reported to have a unique propulsive system of pressure jets at rotor blade tips that eliminates gears, clutches, and shafts of the conventional helicopter. The firm says it uses low-grade fuel, can be operated at less than half the cost of conventional helicopters, and will be half the cost in price . . . . The firm also announced plans for an "airail car" system combining aeronautical principles reported to make the car capable of aircraft speeds with complete safety.

• **Republic Aviation Corporation** has announced the first Long Island flights of the

Republic Aviation Corp. has released this first unretouched photo of its F-105B Thunderchief, a nuclear weapons carrying fighter-bomber powered by a Pratt & Whitney J-75 jet. More than 60 ft. long, the fuselage is area ruled. The supersonic aircraft has a wing (sweptback) span of more than 30 ft. and wind-root air intake ducts for the 15,000-lb. thrust engine.

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All timing, sequence, and other functions designed and built as individual units.

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Each unit is built on an individual, sliding-drawer chassis, with a cable-mounted, cam-locked plug. And, all plug-in units are directly interchangeable.

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Used instead of RC networks to control all timing functions. Individual sets of counting tubes, for each timing function, eliminate complicated switching and gating circuits. Preheat, weldheat and postheat can be individually adjusted, for different operations, at different frequencies.

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Hailed because it permits the interchangeability of units One spare timing unit will serve a multiplicity of functions. Units can be removed or replaced in just a matter of minutes.

EXCLUSIVE "SET-UP/RUN" SWITCH

This exclusive feature allows instant, visual check-out of all timing circuits, before an actual run, and, without the use of any special test instruments—ever!

SEPARATE HEAT CONTROL PANELS

There's one for each of the various heat functions, such as preheat, weld, postheat and current decay. These heat control panels are interchangeable, too!

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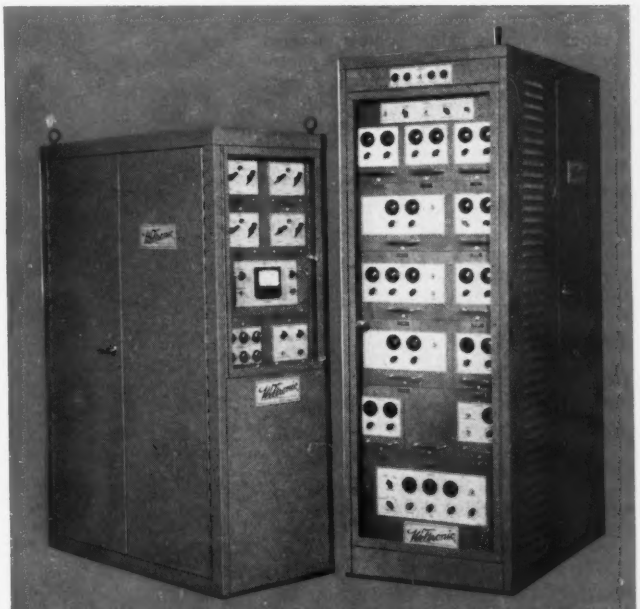

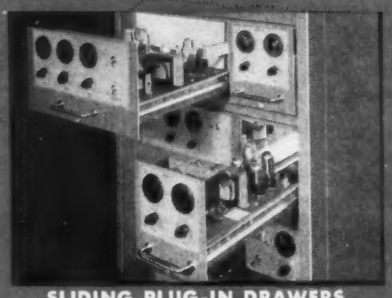

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Control meets Mil specifications.

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F-105B Thunderchief supersonic, nuclear-weapons-carrying fighter-bomber powered by a 15,000-lb. thrust jet engine. A photo-reconnaisance version of the new aircraft also is being produced . . . . Jack Bade has been appointed Director of Flight Operations, and the firm has named Lyle Monkton as his assistant.

• **Ryan Aeronautical Company's** X-13 Vertijet has flown in full operational sequence, the firm announced. The vertical take-off jet is controlled in VTOL flight by a jet reaction control system and by a second, conventional aerodynamic control system during conventional flight. The pilot operates both systems from the usual stick and rudder pedal cockpit controls. Take-off and landing are accomplished by a single hook mounted beneath the fuselage which engages a trapeze-like mechanism built into the bed of a specially designed ground service trailer. Ryan says weight saved by eliminating conventional landing gear may be put back in the form of power plant and fuel and result in improved supersonic performance. The aircraft is said to have extremely high thrust-to-weight ratio inherent in the design and has demonstrated high rates of climb during tests at Edwards AFB. The Ryan - Air Force design is powered by a Rolls-Royce Avon turbojet in the 10,000-lb. thrust class. It has been operated at moderate altitudes and speeds and is solely for research . . . . The Royal Canadian Air Force will get Ryan Firebee jet target drones, the firm announced . . . . A 27-acre industrial site and plant assembly has been acquired in Los Angeles.

• **Solar Aircraft Company** has named two new members to its Board of Directors: Walker G. Dollmeyer, Vice-President—Operations, and Rudolph W. Weitz. C. D. Oberg has been named Director of Sales.

• **Stanley Aviation Corporation** has developed a new Cartridge Actuated Device for cutting of aircraft cable, electrical wiring, and tubing, featuring ultrareliability by virtue of what the firm calls a self-contained dual power source. The training device weighs 0.45 lb., is 4 by 1 by 1¼ in., and can be operated by 600-psi pressure input or electrical ignition. Stanley engineers report operation from −65° to 160°F. to altitudes of 65,000 ft. and under water after a 24-hour soak.

Shell Oil Co. reports the first maximum use of bonded aluminum skin-fiberglass honeycomb sandwich panels in Convair's B-58 Hustler. The panels are bonded with Shell Epon Adhesive 422 Tape. The sandwich panels in the Hustler's primary structures are of phenolic resin-glass fabric honeycomb core which has thin aluminum skins bonded on each side.

• **Systems Laboratories Corporation** has appointed a new slate of corporation officers: James A. Marsh, President; Richard H. De Lano, Executive Vice-President; Wilbert Lloyd, Treasurer; and A. J. F. Clement, Secretary.

• **Thiokol Chemical Corporation** has published a booklet covering the resistance of butyl rubber to various solvents and chemicals. The firm says the study is intended to offer the compounder or the engineer assistance in handling butyl rubber in his shop. The booklet is available upon request to the firm, 780 North Clinton Ave., Trenton 7, N.J.

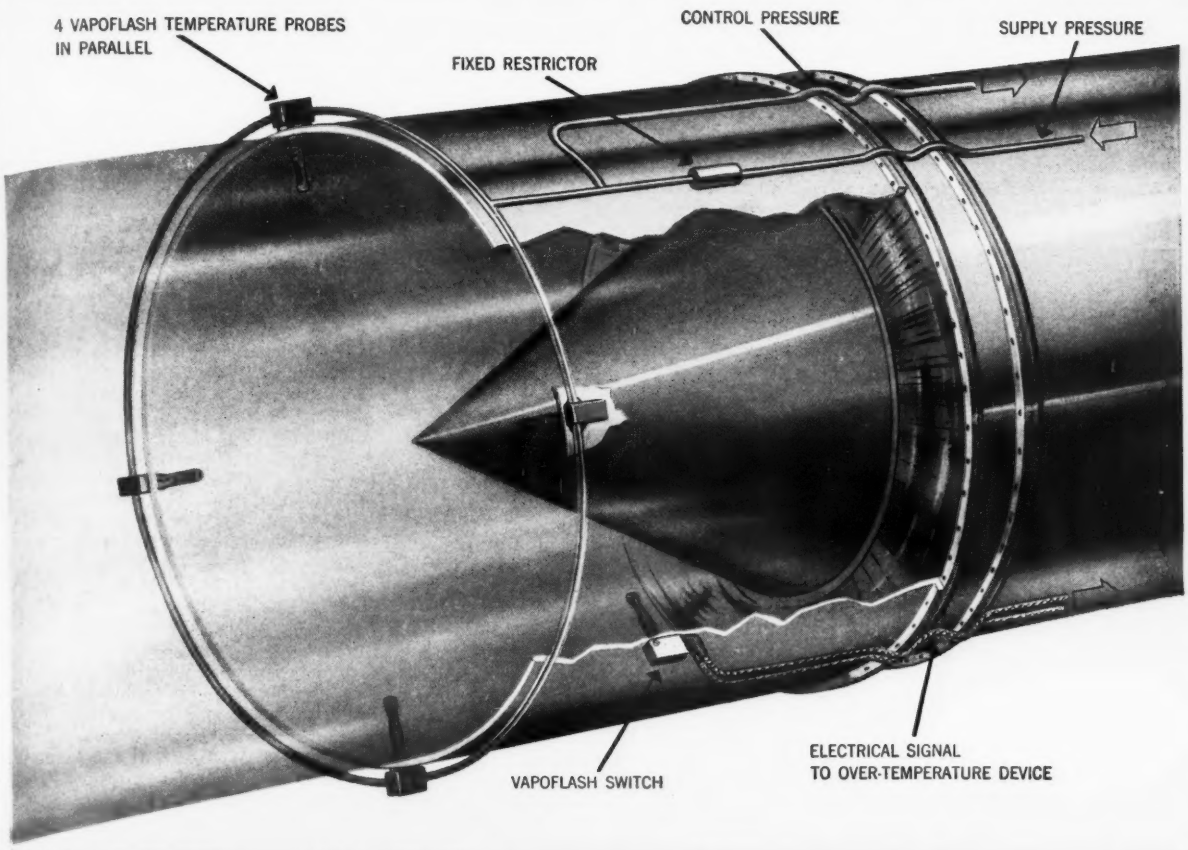
The J-75 axial flow jet engine, built by United Aircraft Corporation's Pratt & Whitney Aircraft Division, is reported to be the most powerful production turbojet in the world. It develops 15,000 lbs. of dry static thrust, according to P&W, nearly 50 per cent more than its slightly smaller predecessor the J-57.

• **Union Carbide Corporation,** Haynes Stellite Company, has published a new 104-page edition of *Hastelloy Corrosion-Resistant Alloys* giving information on four nickel-base alloys. Copies may be obtained from the Advertising Department, 420 Lexington Ave., New York 17, N.Y. . . . Linde Company division has announced new sapphire growing techniques in which large sintered crystals have been produced to compete in price with sintered aluminas and quartz. The division says it is able to supply a large variety of rods, discs, tubes, domes, and balls of sapphire to fill many industrial needs.

• **United Aircraft Corporation,** Pratt & Whitney Aircraft Division, formally announced that it is manufacturing the J-75 turbojet engine. The axial-flow engine is in the 15,000-lb. thrust class, has a close resemblance to the J-57, is slightly larger, and produces nearly 50 per cent more dry thrust. The engine will power Air Force and Navy high-performance fighters and versions of the Boeing 707 and Douglas DC-8. The firm reports that the J-75 has outstandingly low specific fuel consumption and a lower specific weight than the J-57 . . . . Hamilton Standard Division engineers have developed a new air-conditioning system for the B-58 which, they say, drops the air temperature 1,000° in less than a second.

• **United Air Lines, Inc.,** has announced that it will test what it calls a revolutionary method to board and deplane passengers via an all-weather covered "gangplank" at Chicago's O'Hare International Airport. Called an "Aero-Gangplank," it was developed by Lockheed Air Terminals, Inc. The three-section elevated unit consists of a self-powered telescoping span, bridging the second-level distance between the projecting "finger" of the passenger concourse and the plane door.

• **Vertol Aircraft Corporation** has developed four new modifications, three of which are claimed to increase stabilization, for its H-21 helicopter. The improvements include a "differential delta-three" device for longitudinal stability,



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Here Is How VAPOFLASH® Is Used:

Four or more VAPOFLASH PNEUMATIC PROBES are mounted in the turbine exit gas stream to provide an average measurement of the gas temperature. Compressor discharge pressure is fed through a fixed restrictor to a manifold pipe connecting all VAPOFLASH probes. The control pressure leads to the engine fuel control.

When the gas stream temperature acts upon the control band, the VAPOFLASH probes begin to bleed air to the atmosphere, reducing the control pressure proportionally. The power level of this control pressure signal is such that greatly simplified mechanisms can be used to modulate engine fuel flow. The VAPOFLASH technique is equally applicable to afterburner fuel control and variable exhaust nozzle control.

A VAPOFLASH SWITCH provides single-pole, single-throw electrical contact actuation at a desired gas temperature. When calibrated to a higher set point than the pneumatic probe, this unit will provide an electrical control signal for emergency over-ride action.

The VAPOFLASH principle is also available as a temperature probe to control fluid pressure directly as a function of temperature. This configuration is particularly advantageous when applied in a rocket gas generator control.

Get complete technical details and application data about VAPOFLASH in its three forms. We are confident that our long experience and extensive facilities for developing, manufacturing and testing jet engine control components can be of practical value to you. For full information and engineering counsel, please address your inquiry to our headquarters plant, Danbury, Connecticut.

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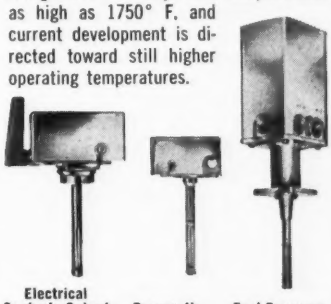
RUGGED...SHOCK RESISTANT... FAST RESPONSE...EASY TO INSTALL

Standard VAPOFLASH control elements are being used in steady state temperatures as high as 1750° F. and current development is directed toward still higher operating temperatures.



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OUR AIRCRAFT PRODUCTS INCLUDE: TURBOJET ENGINE TEMPERATURE CONTROL AMPLIFIERS • ELECTRONIC AMPLIFIERS • PRESSURE SWITCHES FOR ROCKETS, JET ENGINE AND AIRFRAME APPLICATIONS • PRESSURE GAUGES THERMOCOUPLES • FUEL CONTROL VALVES • HYDRAULIC VALVES • JET ENGINE AFTERBURNER CONTROL SYSTEMS

an automatic roll rate damper unit for lateral stability, enlarged vertical tail fins for directional stability, and metal rotor blades for improved performance . . . . William E. Boom has been appointed European Sales Manager and James N. Davis, Assistant to the President of the firm.

• **Vickers Incorporated** has announced a new line of miniaturized motorpumps. The firm reports Model AA-19054 delivers 0.84 g.p.m. at 7,400 r.p.m. and 1,000 psi; the hydraulic pump weighs 1 lb. and the electric motor 7 lbs. Overall length of both the pump and motor is $9^{15}/_{16}$ in.

• **Westinghouse Electric Corporation** has named R. D. Rowley Manager of its metals plant at Blairsville, Pa.

IAS SECTIONS

VTOL and Jet Engines

Atlanta Section

"Aircraft Engine Development Trends" were discussed by Ray T. Lewis at the May 8 meeting. Mr. Lewis is Manager, Commercial Engine Sales, General Electric Corporation.

He briefly traced the growth of jet engines from the Whittle centrifugal flow compressor engine which had 1,400 lbs. thrust and powered the Bell P-59. The J-31 and J-33 engines used in Lockheed P-80's followed this early engine.

The first axial flow compressor engine was the J-35 followed by the J-47, used in B-47's and F-86's. This engine was rated from 5,000 to 7,000 lbs. thrust. The J-79 has 10,000 lbs. thrust, with the commercial model (CJ-805) having the same thrust.

Commercial jets must have extreme reliability and be economical to operate and maintain. Design objectives that must be followed to realize this goal include simplicity, small frontal area, ruggedness, light weight, high specific thrust, easy maintenance, and good growth potential. Mr. Lewis subdivided a typical jet engine into major components to show how these commercial design characteristics are integrated into the engine design. He described some of the design considerations of these components.

Mr. Lewis said the compressor is one of the most important engine components. The axial flow compressor is used extensively because of its relatively reduced frontal area and the two to three times higher pressure ratios that may be obtained compared to a centrifugal-type compressor.

He also described the combustion section behind the compressor which usually consists of several cylindrical cans set annularly about the engine. The major problem in this area is the ability to make successful starts of the engine while in flight at high altitude.

Behind the combustion area is a turbine which supplies power to drive the compressor by means of a shaft. The major problem with this component is operation under high centrifugal loadings while at elevated temperatures. The turbine temperature is one of the limiting factors of engine performance.

▶ W. Z. Stepniewski, Chief, Research and Development, Vertol Aircraft Corporation, spoke on "Basic Performance Aspects of VTOL and STOL Aircraft" at the April 4 meeting.

Mr. Stepniewski covered the "state of the art" and pointed out that no STOL aircraft, meeting generally accepted take-off requirements, has been built, although many proposals for such an aircraft exist.

More important among design considerations for VTOL aircraft is the time to be spent in hovering to satisfy mission requirements. For short hovering times, rotors may be highly loaded and attendant high fuel consumption negligible. But for long hovering times, rotors must have low loadings to reduce fuel consumption.

Mr. Stepniewski showed sketches of several proposed VTOL aircraft and pictures of Vertol's new tilt-wing airplane. He said that it would be used to investigate major problems of stability and control

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A new tool for High Temperature Research
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temperatures from 5,000°K to 15,000°K
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PLASMATRON
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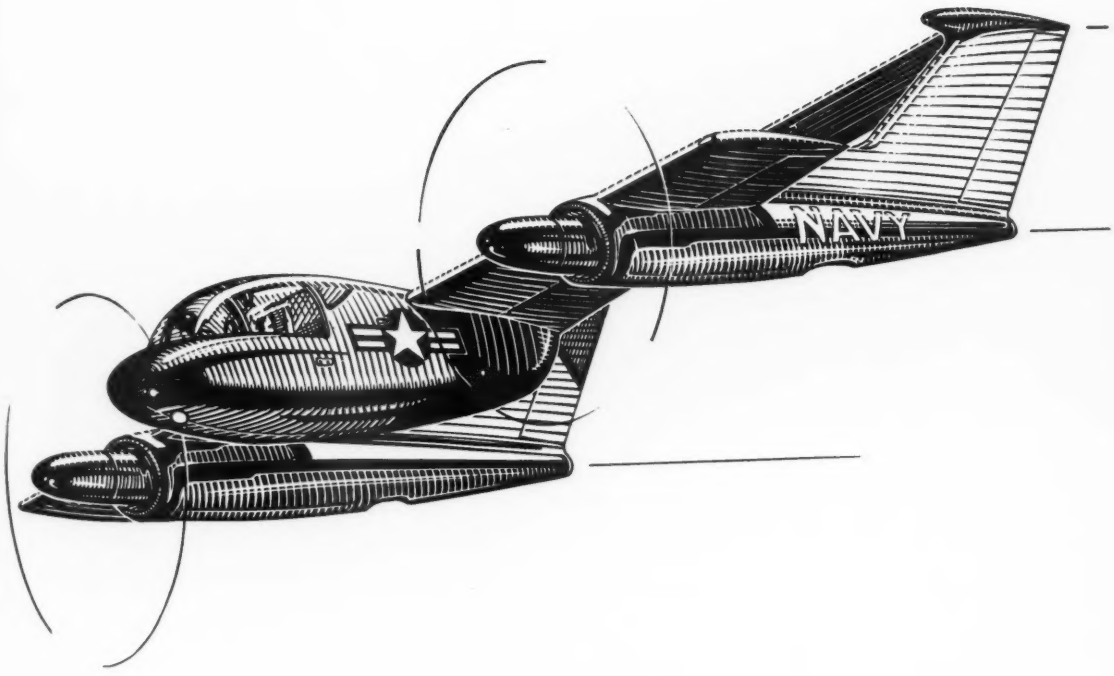
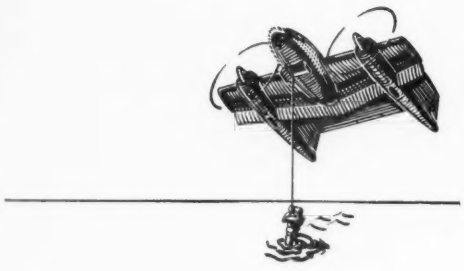
New STOL Aircraft will dart to 300 mph...



...slow to a hover



Kaman Aircraft, under contract to the U.S. Navy, is developing a new and different STOL aircraft concept. Drawing on its experience as a pioneer in the development of turborotor helicopters, Kaman has designed an aircraft which will incorporate the best features of helicopter performance from 0 to 50 mph, and perform as a fixed wing aircraft at speeds up to 300 mph.

This STOL aircraft is another contribution Kaman is proudly making to our National Defense effort.

KAMAN

THE KAMAN AIRCRAFT CORPORATION
Bloomfield, Connecticut

during hovering and transition of the wing from vertical to horizontal.

C. V. WILLIAMS, *Secretary*

Baltimore Section

Paul Garber presented an illustrated lecture on "The Story of the Wright Brothers" before 78 members and guests at the June 6 dinner meeting. Mr. Garber is Head Curator, Aeronautics Exhibit, National Air Museum, Smithsonian Institution.

After his talk, the results of the election of new officers were announced. The new slate includes F. H. Clauser, Chairman; Robert L. Zouck, Vice-Chairman; E. J. Weber, Treasurer; and George C. Pfaff, Secretary. The next meeting will be held in the fall.

R. G. CLANTON, *Secretary*

Chicago Section

Some 100 members and guests attended the annual social meeting May 22 at Glenview Naval Air Station. A new slate of officers elected at this meeting were Chairman—Harry Wiant, Staff Engineer, Cook Research Laboratory; Vice-Chairman—R. A. Schram, Assistant Sales Manager, Shafer Bearing Division, Chain Belt Co.; Secretary—Joseph I. Islinger, Research Engineer, Armour Research Foundation; and Treasurer—Normand L. Sorenson, Flight Engineer, Trans World Airlines.

After the business meeting a film depicting Navy Air Corps history was shown.

R. F. HUNTER, *Secretary*

Air Safety

Hampton Roads Section

Some 60 members, wives, and guests heard Jerome Lederer discuss "Some Nontechnical Problems in Air Safety" at the May 14 meeting. Mr. Lederer is Director of the Cornell-Guggenheim Aviation Safety Center and the Flight Safety Foundation.

He reviewed the present and past story of safety in commercial flight and cited statistics to show that commercial flight is increasingly safer. The casualty rate per passenger-mile today is considerably less than even 10 years ago. Statistics show that it is some three times safer to fly on a commercial air line than to travel by private automobile. But the low casualty rate of the present is not satisfactory for the future. The same rate for expected greater air travel would mean about 500 casualties per year—a rate not acceptable to the public.

Among the nontechnical subjects discussed by Mr. Lederer were problems classed as emotional, legal, and political. Emotional problems include individual preferences based on individual circumstances. Responsible participants involved in accidents sometimes fear to present a complete picture because of possible legal action that might be taken as a result of their testimony. A political problem is created by many committees with inadequate and overlapping responsibilities which hamper improved traffic methods.

Honorary Chairman was Melvin N. Gough, Chief of Flight Research, NACA.

▶ The Annual Career Day Program was conducted by E. C. Polhamus and W. C. Hayes, Jr., of the Section's Student Activities Committee at Huntington High School, Newport News, Va., on April 11.

Some 80 senior high school students attended. The engineering group, each member of which had expressed an interest in some branch of the field, was the largest among 25 vocational groups.

A discussion augmented with slides covered what the engineer does, what training he needs, and what opportunities are available to him. A color film describing research at several NACA facilities also was shown.

Students and faculty members of the school's Vocational Guidance Department were given copies of the IAS brochure.

RICHARD T. WHITCOMB
Recording Secretary

Indianapolis Section

The annual business meeting and election of officers was attended by 85 members and guests on May 14. The dinner meeting was preceded by a social hour sponsored by Marman Products Division, Aeroquip Corporation.

New officers for 1957–1958 are Paul E. Stanley, Purdue University—Chairman; Allen R. Stokke, The Garrett Corporation—Vice-Chairman; R. J. H. Bollard, Purdue University—Secretary; and John M. Adams, Allison Division, General Motors Corporation—Treasurer.

Board members elected include Paul F. Ferreira, Jr., and George J. Clingman, both of Allison Division, and William R. Haney of the William R. Whittaker Co. Elmer F. Bruhn, of Purdue University, was named Representative to the Nominating Committee for Area Councilors.

Chairman Robert E. Saff and committee chairmen reported on activities during 1956–1957. These included briefs from Roger W. Merriman, Membership Committee; Paul E. Stanley, Student Paper Competition; Michael Bifano, Publicity Committee; and Robert L. Myers, Student Interest and Education Activities. Treasurer James D. Anderson presented the financial report.

Highlight of the reports was the increase in membership—more than 30 new members were accepted during the year. The Chairman also cited participation of Corporate Members in Section activities.

After the business meeting two films were shown. The Section will resume activities next fall.

JAMES B. CAHILL, *Acting Secretary*

Institute's 28th Section

Kansas City Section

Three officers of this new Section met at the home of Chairman H. F. Faught on May 28 to set up program and membership committees, review planning for summer field trips, and discuss miscellaneous business in connection with Section operations.

Vice-Chairman M. B. Fannon was appointed Chairman of the Program Committee. Others appointed (subject to their acceptance) were E. K. Parks, S. L. Higginbottom, P. M. Sarles, and T. R. Marks.

Appointed to the membership committee were F. A Rosenthal (Chairman), F. W. Henning, L. Homer Mouden, David A. Hartline, and A. S. Andes (ex-officio member).

Discussion of field trips led to the decision not to arrange one for June because of insufficient time for planning. Under consideration are visits to Westinghouse Electric Corporation's Aircraft Gas Turbine Division and Grandview AFB.

Section Treasurer Paul Hartline was assigned responsibility for dinner meeting arrangements to preserve continuity and efficiency. He will serve as an ex-officio member of the program committee for this purpose.

Several items of action for the Secretary were agreed upon. The three officers present were Chairman Fought, Vice-Chairman Fannon, and Secretary J. R. MacPherson.

The standard draft constitution in the IAS *Section Officers' Guide* will serve as a basis for operation. Preparation of by-laws to supplement the constitution will be undertaken at a later date.

▶ R. P. Kroon of the Steering Committee was toastmaster at the May 15 dinner meeting at which results of the mail ballot for new officers were announced.

Elected to the Advisory Board were R. P. Kroon, R. W. Rummel, A. S. Andes, and V. V. Schloesser. The Section's officers are H. F. Faught, Chairman; M. B. Fannon, Vice-Chairman; J. R. MacPherson, Secretary; Paul A. Hartline, Treasurer; and J. W. Lawton, Section Representative.

After the slate was ratified, the new Chairman suggested formal meetings begin in September to allow time for planning committees to prepare programs.

Robert R. Dexter, IAS National Secretary, explained future plans and current activities of the Institute, dwelling on expanding international activities, the development of an annual International Congress on Aeronautics, publication of abstracts of technical papers, and aspects of Section activity important to IAS Headquarters.

Guest speaker Sidney Eckblaw of the University of Kansas City discussed "The Earth's Atmosphere and Its Circulation." He reviewed the principal wind currents and basic makeup of atmosphere and presented a short film. In addition, an Air Force film, *Aeronautical Oddities*, was shown.

J. R. MACPHERSON, *Secretary*

Rocky Mountain Section

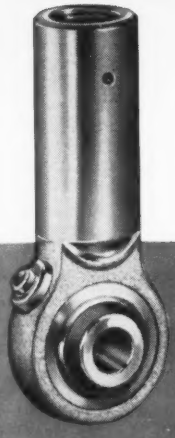
Herman Salmon, Chief Engineering Test Pilot, Lockheed Aircraft Corporation, described problems involved in developing an ejection seat for the F-104 before some 80 members at the April 10 meeting.

The seat, he said, was developed jointly by Lockheed and Stanley Aviation Corporation, the current manufacturer. A variety of configurations were given scale model slingshot tests and full-scale tests

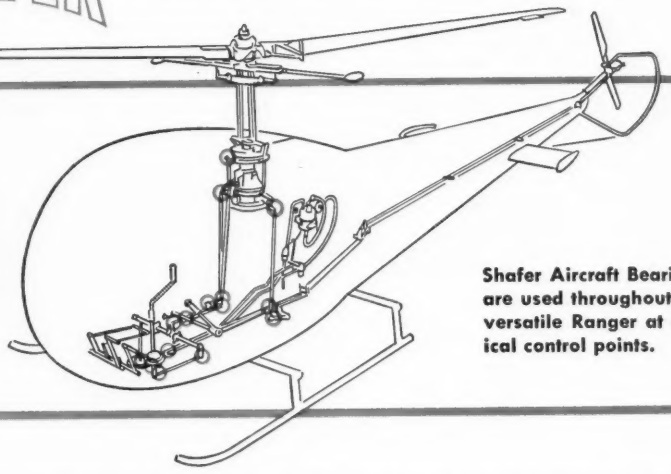
Newest of the famous Bell Model 47 family, the Ranger cruises with its four passenger load at more than 90 m.p.h.

for the toughest control applications

SHAFER® AIRCRAFT BEARINGS



YS-112, one of the many C.A.A.-approved Shafer Bearings used on the Bell Model 47J.



Shafer Aircraft Bearings are used throughout the versatile Ranger at critical control points.

Toughest of all aircraft bearing applications is in the control system of rotary wing aircraft.

Constant vibration, continually varying in-flight deflections of structural members, oscillatory loads, shock loads—all combine to call for the utmost in bearing performance.

Shafer Bearings are specified by Bell engineers because they provide full capacity under all these conditions at all degrees of misalignment to plus or minus 10°. Regardless of size, Shafer Bearings deliver the performance and the greatest load capacity for envelope dimensions and weight—greater than any other self-aligning anti-friction bearings available today!

Shafer rollers align themselves naturally, eliminating roller end wear and race surface scuffing—insuring unrestricted radial capacity under all conditions.

All Shafer Aircraft Bearings provide for relubrication in service—without disassembly or removal from the aircraft structure—of special importance for long life in helicopter applications. This original Shafer feature makes it practical and easy to extend service life three to ten times that of bearings not relubricated.

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SHAFER® CHAIN BELT COMPANY

on a rocket-propelled sled at Holloman AFB.

Mr. Salmon said that a good deal of engineering ingenuity was needed to create a configuration which was aerodynamically stable and which would provide pilot-protection against supersonic blast. Movies of the final configuration showed how stability was achieved by making use of lateral roll-damping fins and a skip-flow generator. The complicated requirement of having the pilot's arms, legs, and body trunk strapped to the seat during separation from the seat after ejection was overcome by using automatic devices. Additional automatic devices open the chute.

In the course of his talk, Mr. Salmon brought out details about design concepts embodied in the F-104. He spoke from personal experience about the plane's flying qualities and told of an instance when he had to bail out because of power failure.

Chairman Allison Arnold announced tentative plans for a visit to Air Defense Command facilities at Ent AFB, Colorado Springs, Colo.

ARTHUR W. GILMORE, *Secretary*

Tullahoma Section

A new slate of officers elected at the June 10 meeting were J. L. Potter, Chairman; H. E. Gardenier, Jr., Vice-Chairman; H. A. Reichmann, Jr., Secretary; and J. A. Millillo, Treasurer.

Don Eastman spoke on "Operations of the Strategic and Defensive Air Forces" after the election.

His discussion covered the capabilities, equipment, personnel, and combat readiness of such Air Force organizations as the Strategic Air Command, Air Defense Command, and SAGE.

WILLIAM T. STRIKE, JR.
Secretary

Balloon Research

Washington Section

Malcolm D. Ross discussed "Investigations With High-Altitude Balloons" at the May 14 meeting. Mr. Ross is Physicist, Air Branch, Office of Naval Research.

The topic dealt with various phases of upper atmosphere research, achieved and possible, with balloons. Developmental efforts of Piccard and Akerman in the thirties resulted in the nylon balloon for flights up to 30,000 ft. for early weather information. Nylon, which was sensitive to temperature changes, gave way to polyethylene and, later, mylar plastic balloons for flights to 100,000 ft. Rockets carrying balloons have made it possible to collect data at 300,000 ft.

Balloons are also used to photograph hurricanes, Mr. Ross said. A balloon ballasted to take advantage of air currents is floated out over the hurricane at 30,000 ft. Altitude is then increased to 90,000 ft. for return over the hurricane with instruments and cameras to take panoramic pictures of the storm below.

Mr. Ross and Lt. Comdr. M. L. Lewis set an unofficial altitude record for manned flight in balloons when they rose to 76,000 ft. Both received the Navy League Annual Award of Merit for this flight.

A scientist from the Naval Research Laboratory added to the meeting informally with a brief discussion of rockets and the satellite in ultrahigh altitude research. He compared information gathered in this manner with that obtainable by balloon research.

Captain S. S. Sherby, USN, May Program Chairman, had scheduled a visit to a fleet carrier for May 14, but the trip was postponed for a future date because of a Navy priority commitment.

Honorary Chairman was Capt. Alfred B. Metsger, USN, Deputy Chief of Naval Research.

G. L. DESMOND
Secretary-Treasurer

STUDENT BRANCHES

Air Force Institute of Technology

Some 90 members and guests saw two movies, *ARDC Staff Film Reports 30 and 31*, at the May 10 meeting. The staff films are classified monthly progress reports of various ARDC projects.

The meeting was sponsored jointly by the Branch and the Honor Society of Pi Epsilon Gamma.

1ST LT. ALIDORE A. JANCAUSKAS
Secretary

Georgia Institute of Technology

A. J. Berryman described Boeing Airplane Company's Pilotless Aircraft Division at the May 13 meeting. He is a Missile Research Engineer at Boeing's Patrick AFB test site.

Mr. Berryman covered the many problems encountered in missile engineering and the progress his firm has made in this field.

During the business meeting a motion to amend the bylaws was approved by a vote of 32 to 1, with six members abstaining. The motion provides for dropping members who fail to pay dues by the third meeting of each quarter.

▶ Raymond J. Volluz, Chief, Supersonic Wind Tunnel at Convair's Daingerfield, Tex., facility, spoke on "Work at Daingerfield" at the April 29 meeting.

He gave a brief history of the facility and said that although work done there was for the Government, all aircraft manufacturers would benefit from it. He showed slides of the plant, high-altitude test facilities, supersonic wind tunnel, and force and pressure equipment.

He concluded with the prediction that in 10 years piloted aircraft will fly 5,000 m.p.h. and piloted rockets, 10,000 m.p.h. He also said manned space flight will be possible in 20 years.

ROY W. HARRIS, JR., *Secretary*

Indiana Technical College

Rex Pierson and Maurice Landford were given awards at the May 7 meeting. Mr. Pierson received the Outstanding Student Award and Mr. Landford the IAS Scholastic Award.

Later, a representative from North American Aviation, Inc., spoke on "Fighter Aircraft." He explained technical problems of building supersonic aircraft.

▶ A picture for the school yearbook was taken at the April 9 meeting and meeting dates for the fall term announced.

Some 40 members attended both meetings.

JACK BOCCALEONI, *Secretary*

Iowa State College

David E. Mellen spoke on the automatic control of manned aircraft at the May 22 meeting. Mr. Mellen is Manager, Autopilot Analysis Division, Minneapolis-Honeywell Regulator Company.

He compared the damping of an aircraft to a spring mass system and explained the need for damping in current aircraft. He also discussed and demonstrated poor, good, and satisfactory damping and the effects of Mach Number and altitude on it.

JOHN ANDERSON, *Secretary*

Massachusetts Institute of Technology

Leonard Arnowitz of The Martin Company discussed Project Vanguard before 75 members on May 14. Mr. Arnowitz is Assistant Project Engineer in charge of flight path for the project.

He explained Project Vanguard in connection with the International Geophysical Year. He described requirements for establishing a vehicle in an orbit and the tolerances necessary to maintain its direction and velocity. An elliptical orbit is best suited because it allows for maximum error within a 200 to 1,400-mile altitude limit.

Stability will be maintained by swivelling the rockets rather than an aerodynamically stable structure form. The missile will be 72 ft. long, weigh 11 tons, and travel 18,000 m.p.h. He described first-phase control in detail and used slides of an artist's conception to illustrate his points.

WILLIAM TOWLE, *Secretary*

North Carolina State College

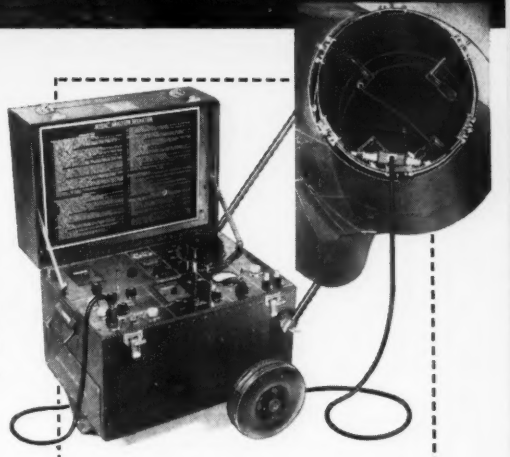
R. P. Petuiolos spoke on "Some Problems of High-Speed Flight" at the April 9 meeting. He is on the staff of North American Aviation's Columbus Division.

One of the items he discussed was the problem of getting high-speed data for design. He showed a movie, *Rocket Sled*

...ARE PROTECTED BY THE B&H

JETCAL® ANALYZER

Two of the most important factors that affect jet engine life, efficiency, and safe operation are *Exhaust Gas Temperature (EGT)* and *Engine Speed (RPM)*. Excess heat will reduce "bucket" life as much as 50% and low EGT materially reduces efficiency and thrust. Any of such conditions will make operation of the aircraft both costly and dangerous. The *JETCAL Analyzer predetermines* accuracy of the EGT and (interrelatedly) Tachometer systems and isolates errors if they exist.



The *JETCAL* ANALYZES JET ENGINES 10 WAYS:

1) The JETCAL Analyzer *functionally* tests EGT thermocouple circuit of a jet aircraft or pilotless aircraft missile for error *without running the engine or disconnecting any wiring*. GUARANTEED ACCURACY is ±4°C. at engine test temperature.

2) Checks individual thermocouples "on the bench" before placement in parallel harness.

3) Checks thermocouples within the harness for continuity.

4) Checks thermocouples *and* paralleling harness for accuracy.

5) Checks resistance of the Exhaust Gas Temperature system.

6) Checks insulation of the EGT circuit for shorts to ground and for shorts between leads.

7) Checks EGT Indicators (in or out of the aircraft).

8) Checks EGT system with engine removed from aircraft (in production line or overhaul shop).

9) Reads jet engine speed while the engine is running with a guaranteed accuracy of ±0.1% in the range of 0-110% RPM. Additionally, the TAKCAL circuit can be used to trouble shoot and isolate errors in the aircraft tachometer system.

10) JETCAL Analyzer enables engine adjustment to proper relationship between engine temperature and engine RPM for maximum thrust and efficiency during engine run (Tabbing or Micing).

ALSO *functionally* checks aircraft Over-Heat Detectors and Wing Anti-Ice Systems (thermal switch and continuous wire) by using TEMPCAL Probes.. Rapid heat rise . . . 3 minutes to 800°F! Fast cycling time of thermal switches . . . 4 to 5 complete cycles per minute for bench checking in production.

Tests EGT System Accuracy to ±4°C at Test Temperature

(functionally, without running the engine)

Tests RPM Accuracy to 10 RPM in 10,000 RPM (±0.1%)

The JETCAL is in worldwide use . . . by the U. S. Navy and Air Force as well as by major aircraft and engine manufacturers. Write, wire or phone for complete information.

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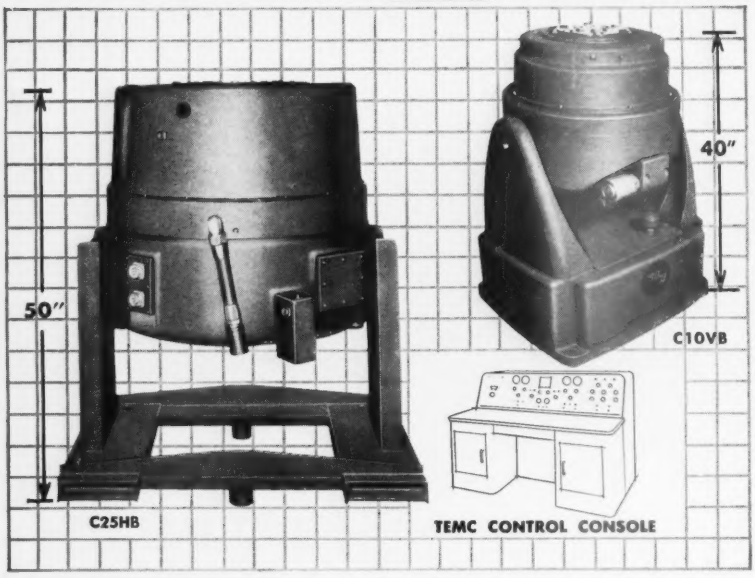
FIGHT VIBRATION WITH VIBRATION



Vibration Testing cuts product development time

Testing components and structures with electrodynamic vibration exciter systems cuts research and development time in aircraft and missile systems. Often within hours, or minutes, the effect of service vibration can be pinpointed.

MB has perfected shaker systems that permit testing to all required specifications, enable engineers to speed product development from blueprint to prototype to production.

COMPLEX MOTION TESTING

Several MB Exciter Systems reproduce complex and random motions. They can subject products to the actual service vibration. The Model C10VB Shaker shown offers the widest frequency range for its force. Model C25HB provides higher forces for higher "g."

ENVIRONMENTAL TESTING

Both the above shaker systems can be used with environmental chambers . . . for "high altitude" and high or low temperature vibration testing. Oil cooled, they don't affect chamber vacuum.

SPECIFICATIONS

MB C10VB System provides . . .
10 "g" on table loads to 145 lbs.
20 "g" on table loads to 57.5 lbs.

Force output:	Band width:
1750 lbs. Sine	5-5000 cps
1050 lbs. RMS	15-2000 cps
3150 lbs. Peak	15-2000 cps

MB C25HB System provides . . .
10 "g" on table loads to 422 lbs.
20 "g" on table loads to 172 lbs.

Force output:	Band width:
5000 lbs. Sine	5-2000 cps
3500 lbs. RMS	15-2000 cps
10,500 lbs. Peak	15-2000 cps

In meeting your requirements, MB offers you advanced designs . . . plus quality construction of shaker, amplifier and control system . . . plus an experienced field service organization.

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HEADQUARTERS FOR PRODUCTS TO ISOLATE . . . EXCITE . . . AND MEASURE VIBRATION

Testing for Flutter, in this connection.

RICHMOND P. BOYDEN
Corresponding Secretary

Oregon State University

The Branch sponsored a paper presentation banquet recently where four members read technical papers scheduled for competition in the West Coast Regional Conference.

First prize of $25 and 1-year free membership went to Jack D. Dennon for his paper "The Design and Development of a Wind Turbine Powered Tethered Rotary Winged Aircraft." Second prize went to Robert L. Balch for "An Experimental Method of Determining Column Critical Load by Measurement of Frequency of Vibration." Dale L. McLellan took third prize for "An Analysis of Prestressed Bolts," and fourth prize went to Walter T. Davey for "A Device for Determining Aircraft Position as an Aid to Aerial Navigation."

The four judges were Edward Jannsen and Robert Sturges of the Aero Club of Oregon; Louis N. Stone, Associate Professor of Electrical Engineering; and R. L. Richardson, Associate Professor of General Engineering.

Mr. Jannsen also presented the IAS Scholastic Award and 1-year free membership to Maurice Rasmussen for attaining the highest scholastic record during junior and senior years.

WILLIAM K. HOWELL, *Secretary*

The Pennsylvania State University

Thirty-five members met to elect new officers at the May 21 meeting. Those elected were Robert H. Dunkelberger, Chairman; James E. McLaughlin, Vice-Chairman; and Robert E. Henderson, Secretary-Treasurer.

John A. Fox, Branch Faculty Adviser, reviewed happenings at the Middle Atlantic Regional Conference which he and 12 members attended.

Kenneth P. Kerr was given the IAS Scholastic Award. Frederick K. Evans and Raymond F. Carlin, Jr., were given the Student Branch Lecture Award.

Three Air Force News Digest films were shown, depicting latest technical and nontechnical Air Force developments.

JERRY C. DUNLAP, *Secretary*

Polytechnic Institute of Brooklyn

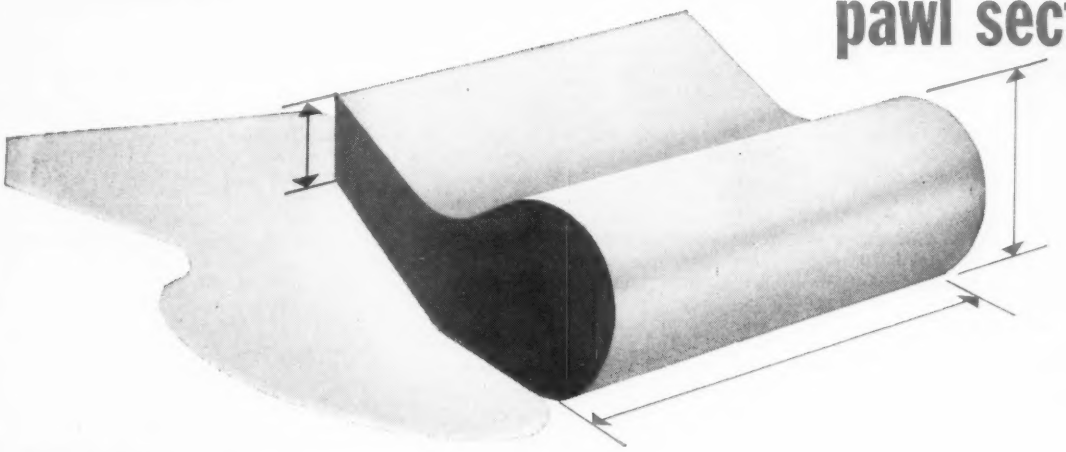
Eugene Sevigny, a senior in aeronautical engineering, drew upon 4 years' experience in helicopter component testing to discuss "The Engineering Aspects of Helicopter Flight" on May 21.

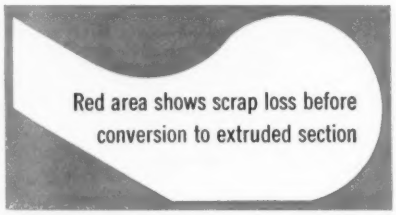
Ordinarily, a high lift airfoil section for the rotor would seem sensible for helicopter hovering ability. But resulting moment produces too much blade twist, and a symmetric airfoil whose center of pressure coincides with the blade's center of gravity must be used.

Normal variation of lift with velocity squared tends to make the outer blade critical for lift. To provide a more nearly linear variation of lift along the blade span, the airfoil's geometry and angle of incidence are varied. The ideal rotor

52% saving

reported with J&L hot extruded cold drawn pawl section





This pawl was previously milled from a ¾" x 1½" hot rolled oil hardening tool steel. Conversion to a cold drawn extruded section cut cost from 45¢ to 22¢ per part.

Here's how extruded sections can cut your cost:

1. Eliminate machining and finishing operations.
2. Reduce scrap losses almost to zero.
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Investigate this new production technique for your shape profiles—within present limits of a design which can be inscribed in a three-inch circle. Available in a wide range of carbon and alloy steels. For specialty alloy and tool steels, submit inquiry. Get complete details by writing to the Jones & Laughlin Steel Corporation, Dept. 526, 3 Gateway Center, Pittsburgh 30, Pennsylvania.

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speed would be that which keeps the tips just below sonic velocity. Actually, maximum tip speed is kept well below half this value to compensate for increased relative velocity felt by the advancing rotor blade.

He said that lifting force on the advancing and receding blades is equalized by applying the Cierva flapping blade effect through articulated or individually hinged blades.

The rotor hub is surrounded by a washer-like wobble plate which moves up for climb; down for descent; and tilts for turning, forward, and backward flight.

ALLEN J. SCHNEIDER
Recording Secretary

Rensselaer Polytechnic Institute

Jack Roberts discussed "Remote Controls of Missiles and Aircraft" at the semester's last meeting on May 8. He is Senior Engineer, Design Department, Aeronautical Equipment Division, Sperry Gyroscope Company.

Arthur Sutherland, newly elected Chairman of the Branch, introduced Mr. Roberts whose discussion covered the history of pilotless aircraft. He began with the Sperry autopilot of 1914, continued with the drone B-17's of World War II, and spoke of current missiles and jet drones. Today's drones are used for many purposes including high-performance targets, structural research, atomic cloud research, and training devices.

Mr. Roberts showed slides picturing the Sperry control system components in the QF-80 jet drone and a film of this drone in action. He also presented the Branch with a large color photo of the QF-80 and answered questions after his talk.

CHARLES KROMER, *Secretary-Treasurer*

San Diego State College

V. J. Schack, Instrumentation Chief, Flight Test Group at Convair, San Diego, spoke on "Flight Test Function" at the May 14 meeting of the Branch which was joined by its SAE and ASCE counterparts.

Mr. Schack covered the various functions of a flight test group and explained its results in the new technical era created by modern aircraft. Ten years ago an aeronautical engineer could conceive an overall picture of a specific aircraft and analyze performance characteristics from results of flight testing. But today, aircraft are so complex that the flight test group must be composed of a number of specialists—e.g., fluid flow, electronic, structure, aerodynamic, thermodynamic, and others—in order to obtain a complete analysis of results.

He said that the principal factor behind this is the transition from subsonic to supersonic speeds. The importance of flight testing lies in the fact that good results save money in the manufacture of high-cost aircraft.

JAMES R. FRAHM, *Secretary*

Stevens Institute of Technology

G. Wynette of North American Aviation, Inc., Columbus Division, was guest speaker at the May 15 meeting. His talk was given in conjunction with the film, *Application of Rocket Sled Techniques to Flutter Testing*.

After explaining the importance of proper weight distribution in modern aircraft, he went on to cite numerous opportunities for engineers in aviation.

This was the last meeting of the spring semester. The next meeting is scheduled for September.

JAMES E. ROE
Corresponding Secretary

University of Alabama

Officers for the fall semester were elected at the May 16 meeting. They are Thomas J. Lee, Chairman; Gordon Johnson, Vice-Chairman; William F. Britt, Secretary; and Anthony Gregoire, Treasurer. James O. Nichols will remain as Faculty Adviser.

Thomas J. Lee read a paper, "Theory and Design of a Shock Tube for Use as an Aerodynamic Test Facility," which he planned to enter in the Southeastern Regional Student Conference.

Thirty-eight members saw two films loaned by the AFROTC at the April 4 meeting. The films were *Air Science in Action* and *USAF News Review*.

The first film demonstrated the use of computers, decompression chambers, ejection seats, spin tunnels, and ground-to-air, air-to-air, and air-to-ground missiles. Precision bombing, use of an "electronic brain," and automatic target plotting were shown.

The news film showed various phases of Air Force operations including B-58 flight tests.

CHARLES WELLS, *Secretary*

University of Illinois

"Kármán Vortex Effects on the Design of Slender Missiles" was discussed by Robert S. Goldman at the last meeting of the semester on May 8. Mr. Goldman is on the Dynamics Staff, The Martin Company, Baltimore.

His talk centered on the problem of controlling damaging vibrational stresses which occur when the "Kármán vortex" exists. Particular solutions were obtained empirically because of the difficult nature of the problem. Various configurations and spoiler arrangements were suggested to break up the vortices. Mr. Goldman illustrated his talk with slides. He also showed a film of the Tacoma, Wash., bridge collapse to illustrate the danger of resonant vibrational stresses.

▶ Lester W. Smith spoke on "Vibration Control in Aircraft Equipment" at the April 24 meeting. Mr. Smith is Supervisor, Vibration Test and Analysis, Hamilton Standard Division, United Aircraft Corporation.

He restricted his discussion to propellers to simplify the topic and, in particular, considered four-bladed propellers. He covered causes, detection, and elimination of symmetric and unsymmetric undesirable vibrations. Slides of testing setups illustrating strain-gage location and graphs of high vibration stress areas were shown.

After the talk members engaged Mr. Smith in a question and answer discussion.

▶ At the April 10 meeting J. Steinman spoke on "An Approach to Structural Reliability in Missile Design." He is Head, Structures and Materials Section, Weapons Systems Development Laboratories, Hughes Aircraft Company.

Mr. Steinman discussed aerodynamic heating and aeroelastic and general structural problems of Falcon-type missiles. He showed slides of quantitative graphical representations of various parameters. Several mathematical formulas illustrated how solutions to particular problems might be obtained. After his talk, the film *This Is the Falcon* was shown.

JERRY L. HARPER, *Secretary*

University of Kentucky

David Igleheart, a Branch member and electrical engineering student, spoke on "Successful Cargo Delivery" at the May 9 meeting.

He explained how cargo is damaged by ground winds which drag it a considerable distance. For cargo delivery by parachute to be successful, a device must be perfected which will release the parachute upon ground contact. He said he was working on such a device at Wenner-Gren Aeronautical Research Laboratory and explained its full operation.

Later, officers for the fall semester were elected. They are John Schiller, Chairman; Bill Ogden, Vice-Chairman; Joe Arnett, Secretary; A. L. Wittwer, Treasurer; and William R. Yount, Program Chairman.

A. L. WITTWER, *Treasurer*

University of Tulsa

Richard A. Walz and James P. Fulton, graduating members, have accepted positions at Lockheed's Missiles Division and Douglas Aircraft's Tulsa Division.

Mr. Walz was nominated for the IAS Scholastic Award on May 9. W. A. White was nominated for the Lecture Award. His paper, "Development and Analysis of Design Loads for a Typical Wing-Fuselage Intersection," was entered in a Regional Student Conference.

▶ Officers elected May 2 for the fall semester were W. A. White, Chairman; David Conn, Vice-Chairman; and Kenneth Roger, Secretary-Treasurer.

Two films from Northrop Aircraft, *The Fang* and *The Snark*, were shown after the election.

▶ Highlighting Branch activities during spring and fall were a film on *Light Metal Forgings*, from Wyman-Gordon Company, and a field visit to Douglas' Tulsa Division.

The film explained processing necessary to manufacture large aluminum press forgings. The Douglas visit included an inspection tour of the YC-132 cargo transport and a high-altitute test chamber.

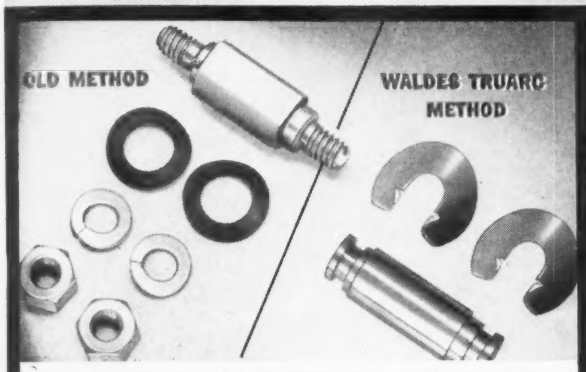
JAMES P. FULTON, *Chairman*

University of Washington

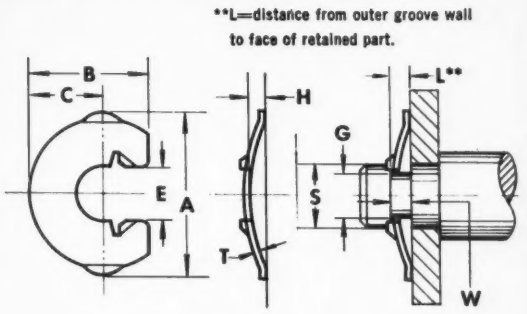
Daniel McBeth spoke on the "Boeing Gas Turbine" at the May meeting. Mr. McBeth is Chief, Application & Evaluation Unit, at Boeing Airplane Company's Industrial Products Division.

He said Boeing began work on a gas turbine in 1943 with a staff of three men. The

New Waldes Truarc locking-prong ring functions as spring, shoulder, fastener...and STAYS PUT!



Above assembly shows how 2 Waldes Truarc Locking-Prong Rings (Series 5139) replaced 6 parts...eliminated threading operation... and need for skilled labor.



WALDES TRUARC LOCKING-PRONG RING (Series 5139)

U. S. Pat. Pending

Ring No. 5139–	SHAFT		RING DIMENSIONS												average ultimate shear strength lbs.*	GROOVE DIMENSIONS						resilient end play take up L max–L min
	Dia. S	tol.	A	tol.	B	tol.	C	tol.	E	tol.	H	tol.	T†	tol.†		Dia. G	tol.	Width W	tol. –.000	L min.	L max.	
12	.125	±.002	.340	±.010	.307	±.010	.166	±.005	.086	±.004	.050	±.010	.010	±.0013	400	.082	±.0015	.045	+.005	.035	.045	.010
★15	.156	±.003	.380	±.010	.330	±.010	.184	±.005	.108	±.004	.055	±.010	.010	±.0013	600	.104	±.002	.050	+.005	.035	.045	.010
18	.188	±.003	.445	±.010	.390	±.010	.213	±.005	.130	±.005	.060	±.010	.015	±.0015	900	.124	±.002	.065	+.005	.045	.055	.010
25	.250	±.003	.581	±.010	.500	±.010	.280	±.005	.172	±.005	.070	±.010	.015	±.0015	1000	.165	±.002	.070	+.005	.050	.065	.015
31	.312	±.003	.744	±.010	.620	±.010	.360	±.005	.234	±.005	.095	±.010	.018	+.001 –.002	1300	.228	±.003	.080	+.005	.080	.095	.015
★37	.375	±.003	.853	±.015	.740	±.010	.427	±.005	.280	±.005	.130	±.010	.020	±.002	1900	.270	±.003	.105	+.005	.090	.115	.025
★43	.438	±.003	.960	±.020	.820	±.020	.475	±.010	.337	±.010	.130	±.010	.020	±.002	2200	.327	±.003	.105	+.005	.095	.120	.025

Additional Sizes Under Development ★Production dies not available as of date of printing †Applies to unplated rings only *Recommended safety factor =3 to 4.

The Waldes Truarc Locking-Prong Retaining Ring is a new, low cost, radially applied fastener which can be locked positively in its groove and used as a shoulder against rotating parts. It is primarily intended for use in the automotive, electronic and aeronautical industries.

This radially applied ring locks positively in its grooves by means of two prongs at the open end. Because of its high thrust-load capacity the Waldes Truarc Locking-Prong Ring may be used as a shoulder against rotating parts. Its bowed construction provides for end-play take-up in the assembly and makes less critical the tolerances required for the parts being fastened. Since it serves as a spring as well as a shoulder, this ring eliminates the need for springs, washers, and other accessory fastening devices.

Whatever you make, there's a Waldes Truarc Retaining Ring designed to improve your product...to save you material, machining and labor costs. They're quick and easy to assemble and disassemble, and they do a better job of holding parts together. Truarc rings are precision engineered and precision made, quality controlled from raw material to finished ring.

36 functionally different types...as many as 97 different sizes within a type...5 metal specifications and 14 different finishes. Truarc rings are available from 90 stocking points throughout the U. S. A. and Canada.

More than 30 engineering-minded factory representatives and 700 field men are available to you on call. Send us your blueprints today...let our Truarc engineers help you solve design, assembly and production problems...without obligation.

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☐ Please send me sample Locking-Prong Rings. (please specify shaft size_____)

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firm has since extended this work into a multimillion dollar business. Boeing turbines are designed for industrial purposes requiring high power rating.

They are in use with light aircraft, helicopters, small boats, transport trucks, and electric generator units. One of the main reasons that turbines have not replaced piston engines is their high specific fuel consumption. But Boeing is confident that economy can be improved so that turbines may compete with piston engines.

DONOVAN J. GIESE, *Secretary*

University of West Virginia

Members elected a new slate of officers for the fall semester at the May 22 meeting. New officers are Prof. Leon Z. Seltzer, Honorary Chairman; Dick Deakins, Chairman; Tom Nale, III, Vice-Chairman; Al Zimmerman, Secretary-Treasurer; and Jack Hunter, Corresponding Secretary.

Chester Whitehair was named Publicity Chairman upon a motion made by Al Zimmerman. Ray Borst suggested the Branch invite a Boeing engineer to discuss turbines at the first fall meeting.

▶ Robert Howard, an alumnus, spoke on problems and techniques of structure design at the May 2 meeting. Mr. Howard is a member of Stress Department, North American Aviation, Inc.

His discussion was augmented by a film, *The Application of Rocket Sled Techniques to Flutter Testing.*

Al Zimmerman gave a report on the Student Leadership Conference. Mike Foruney and Steve Lewellan reported on progress of the engineering show.

DICK DEAKINS
Corresponding-Secretary

University of Wyoming

The final meeting of the semester was held May 15 in the home of Faculty Adviser A. B. Stafford. Officers elected for the next semester were F. Montgomery, Chairman; Dean Hagmann, Vice-Chairman; Robert J. Miller, Secretary; and William E. Odell, Treasurer.

The 15 members present approved a motion to name a reporter to take charge of all publicity and public relations matters. A membership committee of one member from each class was set up for better contact with students who may be potential members.

In other business, the Branch decided to discontinue joint meetings with the ASME Branch because of increased IAS Branch growth.

ROBERT J. MILLER, *Secretary*

U.S. Naval Postgraduate School

Alex Charters of NACA's Ames Aeronautical Laboratory spoke on "Research in Very High Speed Aeronautics" at the May 22 meeting. He discussed problems associated with flight in the speed regime of a satellite vehicle or an ICBM. After explaining testing methods with guns, rockets, and hypersonic shock tubes, he showed a working model of a free-flight range.

The projectile, a .22-caliber rifle bullet, was fired and photographed by spark illumination during its 6-ft. travel for the 25 members and guests present. A rapidly developed photo was distributed among the audience. Several projectile nose shapes were demonstrated and discussed during a later question period.

▶ Haydon Gordon discussed "Nuclear Rocket Propulsion" at the May 8 meeting. Dr. Gordon is Division Leader, Nuclear Propulsion Division, University of California Radiation Laboratory.

His talk centered on problems of using a nuclear reactor as a heat source for a rocket. The advantages of such an arrangement and the variety of engineering problems concerned with the proposal were cited. Dr. Gordon augmented his talk with slides and later conducted a question period.

Some 35 members and guests heard the classified lecture.

GEORGE E. JESSEN
Corresponding Secretary

Wayne State University

New officers elected at the May 29 meeting were Larry Phillips, Chairman; William Glunt, Vice-Chairman; Richard Collins, Treasurer; and William Stevens, Secretary.

A film *New Acts on the Highwire* was shown. Made by Bell Aircraft Company,

"PONY POWER" MOTORS

that give stamina to your products

Lamb Electric ***fractional*** horsepower motors, like the small horses of the famed western-pioneer-day Pony Express, are developed for *stamina.*

Their dependability, and efficiency (optimum weight-size-horsepower ratio) are qualities that result from proper design and careful manufacture by personnel with many years of experience in the small motor field.

May we demonstrate how Lamb Electric Motors can bring these advantages—and also perhaps lower costs—to *your* products?

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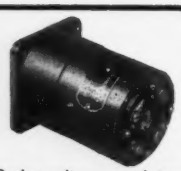
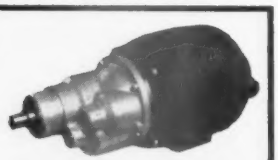
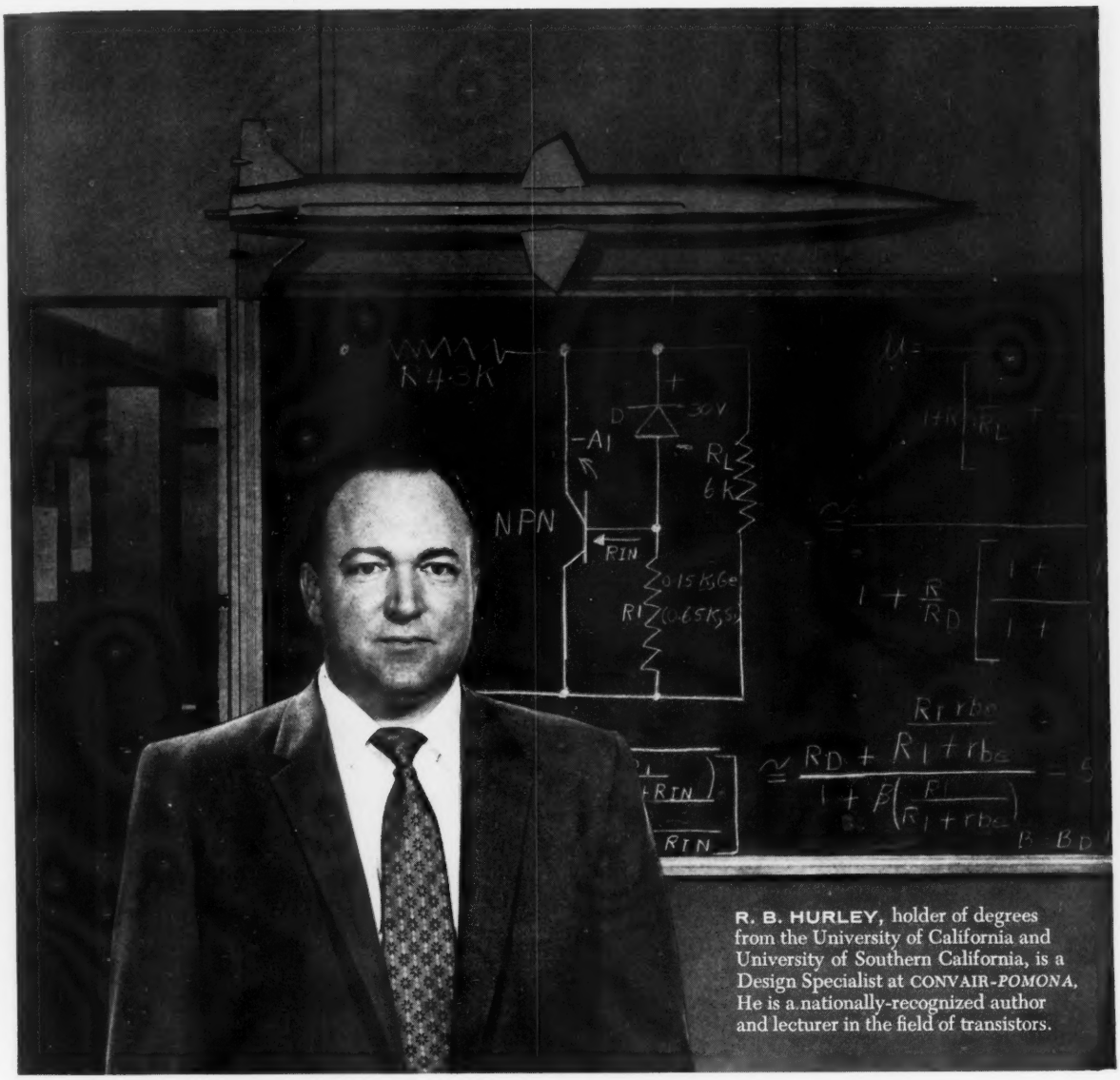
SPECIAL APPLICATION FRACTIONAL HORSEPOWER MOTORS


Radar voltage regulator gear motor.

A rugged high-torque, high-speed motor.


Motor with efficient spur gear speed reducer.



R. B. HURLEY, holder of degrees from the University of California and University of Southern California, is a Design Specialist at CONVAIR-*POMONA*. He is a nationally-recognized author and lecturer in the field of transistors.

"Engineers—here's how we're taking part in the electronics revolution toward solid state devices"

"Here at CONVAIR-*POMONA*, we are constantly studying ways to apply the new miniature solid state electronic devices: the diode, rectifier and transistor. So new is this semiconductor infant, and so vast its future – both for the military and industry – that our teams of electronics engineers actually 'go to school' under some of the foremost experts in the field.

"As the *first* fully-integrated missile plant in the U.S., CONVAIR-*POMONA* designs and builds the Navy's TERRIER supersonic missile. And, realizing the potential value of solid state devices in meeting the critical requirements of such airborne missiles, we initiated a 'transistor program' early in 1953. This program has multiplied many times to become one of the most important in the industry.

"You, as an engineer, can appreciate the tremendous expansion that will come in the application of solid state electronic devices in the next few years. And you can readily understand the advantages of studying and working with these devices, guided by the advanced thinking you will find at CONVAIR-*POMONA*.

"You'll like the atmosphere here, where you see and feel accomplishment. And you will enjoy living in Southern California's beautiful Pomona valley. For greater career opportunity – *for your future's sake* – send for more information about CONVAIR-*POMONA today!* Write to: Engineering Personnel, Dept. 3-N.

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it depicts the use of a helicopter to patrol high power lines through the mountains of the west.

▶ William A. Stevens, a Junior and member of the Branch, spoke on "Ion-Rockets as a Means of Suitable Power for Space Craft" at the May 2 meeting.

Mr. Stevens presented his paper for those who would not be able to hear it at the regional student conference. He compared ion-rockets with liquid rockets describing the advantages and disadvantages of both.

Vice-Chairman Edward Coleman gave a brief estimate of cost and a description of a tour to North American Aviation's Columbus facility.

A color film *New Power for Flight*, depicting development and use of the turboprop engine, was shown at the close of the meeting.

MAX D. RUSSELL, *Secretary*

MEMBERS ELECTED

The following applicants for membership or applicants for change of previous grades have been admitted since the publication of the list in the last issue of the Review.

Elected to Associate Fellow Grade

Cox, Donald D., Weight Unit Chief, Boeing Airplane Co. (Seattle).

Dukes, Wilfred H., Chief, Struct. Analysis, Bell Aircraft Corp. (Buffalo).

Edwards, Sir George R., B.S. in Engrg., Managing Dir., Vickers-Armstrongs (Aircraft), Ltd. (Weybridge).

Franz, Anselm, Dr. Eng., V-P, Lycoming Div., Avco Manufacturing Corp. (Stratford).

Gagge, Adolf P., Ph.D. in Physics, Col., USAF; Deputy Comdr., Sciences, AF School of Scientific Research (Washington).

Graves, Douglas E., B.S. in Civil Engrg., Proj. Engr., Boeing Airplane Co. (Seattle).

Harper, Charles W., B.S. in M.E., Branch Chief, 40 × 80 Ft. Wind Tunnel, NACA (Moffett Field).

Haynes, Emanuel, M.M.E., Deputy Dir., Aero. Sciences, AF Office of Scientific Research.

Liddell, Robert B., B.S. in Ae.E., Asst. Chief, Aerodynamics, Republic Aviation Corp. (Farmingdale).

Monaghan, Reginald J., M.A. in Math., Supt., Experimental Hypersonics and High Temperature Gas Dynamics Sect., Ministry of Supply, Royal Aircraft Establishment (Farnborough).

Mulholland, Donald R., B.S. in M.E., Western Coordinator, NACA (Los Angeles).

Nettles, John C., B.S. in E.E., Assoc. Branch Chief, 8 × 6 Ft. Supersonic Wind Tunnel, NACA (Cleveland).

Robson, D. A. L., B.Sc., Deputy Dir., Aircraft, British Joint Services Mission (Washington).

Schueller, Carl F., B.S. in Ae.E., Head, 10 × 10 Ft. Supersonic Wind Tunnel, NACA (Cleveland).

Wadkovsky, Alexander, B.S. in Ae.E., Proj. Engr., Republic Aviation Corp. (Farmingdale).

Yackle, Albert R., B.S. in M.E., Chief, Special Projects, Kellett Aircraft Corp.

Transferred to Associate Fellow Grade

Bates, Dana B., A.B., Indus. Designer, Canadair, Ltd.

Bikle, Paul F., B.S. in Ae.E., Tech. AF Flight Test Center (Edwards AFB).

Budish, Nathan N., B.S. in Ae.E., Assoc. Prof., Aero. Engrg., Princeton Univ.

Carder, Alden B., B.S. in Ae.E., Mgr., Testing Div., Douglas Aircraft Co., Inc. (Edwards AFB).

Charters, Alexander C., Ph.D. in Ae.E., Aero. Research Scientist, Ames Aeronautical Lab., NACA (Moffett Field).

Chawla, Jagannath P., Dr. of Ae.E., Specialist in Dynamics, Flutter & Vibration, Hughes Aircraft Co. (Culver City).

Clevenson, Sherman A., M.S., Aero. Research Engr., NACA (Langley Field).

Cornell, William G., Engrg. Consultant, Aerodynamics, Jet Engine Dept., General Electric Co. (Evendale).

Ervin, Burl H., M.S. in M.E., Chief Analytical Engr., Aircraft, Rheem Manufacturing Co.

Korff, Walter H., Supvr., Production Design Analysis, Lockheed Aircraft Corp. (Burbank).

Love, Eugene S., B.S. in Ae.E., Head, Hypersonic Tunnels Branch, NACA (Langley AFB).

Lutz, Robert J., B.S. in Ae.E., Asst. to V-P, Engrg., Convair Div. (San Diego), General Dynamics Corp.

Mason, Maxwell, M.S. in Ae.E., Research Physicist, Hughes Aircraft Co. (Culver City).

McCarty, Lewis C., Jr., Exec. Asst. to V-P, Engrg., Avro Aircraft, Ltd. (Toronto).

McJones, Robert W., Self-employed, Consultant.

Naiman, Irven, B.S. in Physics, Member of Tech. Staff, Hughes Aircraft Co. (Culver City).

Oswald, Telford W., Ph.D. in Aero., Sr. Member of Tech. Staff, Hughes Aircraft Co. (Culver City).

Papen, George W., B.S., Mgr., Production Engrg. Dept., Lockheed Aircraft Corp. (Burbank).

Rumph, Lewis B., Jr., M.S. in Ae.E., Head, Aero Dept., The RAND Corp.

Sisson, Thomas U., B.S. in Engrg., Capt., USN (Ret.); Military Adviser, Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Solomon, George E., Ph.D. in Physics, Mgr., Aerophysics Dept., Guided Missiles Research Div., The Ramo-Wooldridge Corp.

Strible, Ferdinand C., Jr., B.S. in M.E., Staff Engr., Aircraft Div., Hughes Tool Co.

Thomas, Charles F., B.S. in Ae.E., Military Relations Mgr., Lockheed Aircraft Corp. (Burbank).

Truitt, Robert W., Ph.D. in Appl. Mech., Prof. & Head, Aero. Engrg. Dept., Virginia Polytechnic Institute.

Walkover, Louis J., B.S. in Ae.E., Supvr., Prelim. Design Sect., Advanced Engrg. Dept, Missile Devel. Div., North American Aviation, Inc. (Downey).

Elected to MEMBER Grade

Archibald, Russell D., M.S. in M.E., Capt., USAF; Proj. Officer, WADC.

Baumann, Billy F., Chief Engr., Royal Jet, Inc.

Bay, Donald B., B.S. in Engrg., Proj. Engr., Continental Aviation & Engineering.

Beisel, John R., B.S. in M.E., Sr. Engr., The Martin Co. (Baltimore).

Brady, James F., Jr., B.S. in M.E., Devel. Proj. Engr., Convair Div. (San Diego), General Dynamics Corp.

Breiling, Robert W., B.S. in Electronic Physics, Product Planner, Aircraft Instrumentation, General Electric Co. (West Lynn).

Brizendine, John C., M.S. in Ae.E., Test Proj. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Brown, Donald B., B.S. in M.E., Sr. Flight Test Engr., North American Aviation, Inc. (Los Angeles).

Brust, Charles K., Jr., B.S., V-P & Chief Engr., Armament Components Div., Townsend Co.

Buller, Elmer H., B.S. in M.E., Research Engr., Lewis Flight Propulsion Lab., NACA (Cleveland).

Carlson, Vincent A., B.S. in Civil Engrg., Asst. Proj. Engr., Convair Div. (San Diego), General Dynamics Corp.

Cullin, William H., M.S. in Ae.E., Comdr., USN; Comdr., Helicopter Desk, Aircraft Engrg. Material Div., Comdr. of Aircraft Pacific Staff, USN (North Island).

Davenport, John F., B.S. in Ae.E., Design Specialist, Hayes Aircraft Corp. (Birmingham).

Doennebrink, Frederick A., B.S. in M.E., Devel. Engr., General Electric Co. (Schenectady).

Dorman, B. L., B.S. in M.E., Mgr., Test & Field Service Div.; Dir., Corporate Long Range Planning, Aerojet-General Corp.

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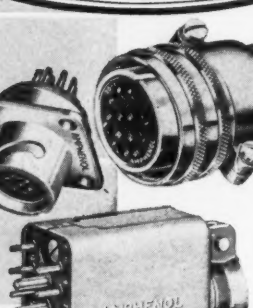
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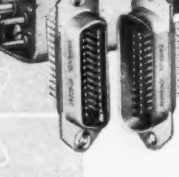
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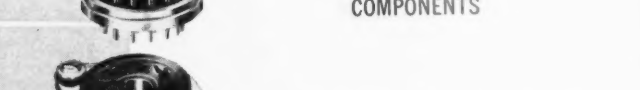

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Ferris, John R., M.S. in M.E., Sr. Research Engr., Research Div., Curtiss-Wright Corp. (Quehanna).

Fisher, Eugene K., B.A., Dept. Head, Missile Systems Div., Lockheed Aircraft Corp. (Van Nuys).

Frey, Sherwood C., M.S. in Physics, Dir., Military Operations Research Div., Lockheed Aircraft Corp. (Burbank).

Geary, John C., M.S. in Ae.E., Capt., U.S. Army; Chief Flight Test, U.S. Army Transportation Aircraft Test & Support Activity (Ft. Rucker).

Grady, Leonard P., B.S. in Physics, Research Engr., Allied Research Associates.

Heath, Donald P., B.S. in Chem Engrg., Supvr., Fuels Sect., Socony Mobil Oil Co., Inc. (Paulsboro).

Henshaw, John T., Sr. Lecturer in charge of Aero. Engrg., Royal Technical College.

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Hoercher, Henry E., B.S. in M.E., Assoc. Scientist, Avco Research & Devel. Div., Avco Manufacturing Corp. (Lawrence).

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Jump, Stephen H., B.S. in M.E., Head, Army, Navy, Marine Projects Admin., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Kawasaki, Toshio, B.S. in Math., Research Fellow, California Institute of Technology.

Kelly, Joseph A., B.S. in Ae.E., Chief, Aerophysics, Motorola, Inc.

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Mazzitelli, Frederick R., B.S. in Ae.E., Chief, Aerodynamics R&D, Vertol Aircraft Corp.

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Pindzola, Michael, B.S. in M.E., Mgr., Engr. Staff, Propulsion Wind Tunnel, ARO, Inc.

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Ryder, Frederick L., Dr. Eng. Sc. in E.E., Member, Scientific Research Staff, Republic Aviation Corp. (Farmingdale).

Schoen, William C., B.S. in Ae.E., Group Leader, Aero. Dept., Grumman Aircraft Engineering Corp.

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Sittig, Marshall, B.S. in Chem. Engrg., Pres., American Lithium Institute, Inc.

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Stankiewicz, Louis J., B.S. in M.E., Mgr., Seal Engrg., Cleveland Graphite Bronze Co.

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Wells, Maxin D., B.A. in Educ., Supvr., Engrg. Flight Test Operations, North American Aviation, Inc. (Palmdale).

Wilson, Lloyd H., Ph.D., Sect. Head, Lockheed Aircraft Corp. (Sunnyvale).

Wolko, Howard S., M.S. in M.E., Head, Contractural Struct. Research Group, Bell Aircraft Corp. (Buffalo).

Wylly, Alexander, Ph.D. in Ae.E., Dir., Mil. Research, Planning Research Corp.

Yonemoto, Noboru, M.S. in E.E., Test Engr., Northrop Aircraft, Inc. (Hawthorne).

Youtcheff, John S., B.A. in Physics, Operations Analyst, MOSD, General Electric Co. (Philadelphia).

Zimmerman, Arthur H., B.S. in Ae.E., Sr. Aerodynamics Engr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Transferred to MEMBER Grade

Cheung, L. T., B.S. in M.E., Sr. Struct. Engr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Ciccarello, James L., B.S. in Ae.E., Power Plant Staff Engr., Republic Aviation Corp.

Coburn, Robert S., B.S. in Ae.E., Flight Test Proj. Engr., North American Aviation, Inc. (Downey).

Cohen, Jerome L., B.A. in Chem., Design Engr., The Edo Corp.

Cunningham, Bernard E., B.S. in Ae.E., Aero. Research Scientist, Ames Aero. Lab., NACA (Moffett Field).

Eckber, Donald P., B.S. in Ae.E., Head, Compressor Sect., Lycoming Div., Avco Manufacturing Corp.

Fink, George E., Service Rep., Fairchild Aircraft Div., Fairchild Engine & Airplane Corp. (Hagerstown).

Foster, Ned R., B.S. in Ae.E., Sr. Proj. Engr., Aeroproducts Operations, Allison Div., General Motors Corp. (Dayton).

Freelin, Joseph R., B.S. in Ae.E., Sr. Struct. Engr., Convair Div. (San Diego), General Dynamics Corp.

Glass, James C., B.S. in Engrg., Design Engr., Western Air Lines, Inc.

Gold, Richard R., Ph.D. in Ae.E., Research Engr., Hughes Aircraft Co.

Hoel, Robert A., M.S. in Ae.E., Proj. Engr., Armament Sect., Minneapolis-Honeywell Regulator Co. (Minneapolis).

Jarrett, Henry W., Jr., B.S. in Ae.E., Asst. Proj. Engr., USAF (Wright-Patterson AFB).

Lehrer, Alfred, B.S. in Ae.E., Struct. Engr., Lockheed Aircraft Corp.

Macey, Ralph E., B.S. in Ae.E., Aerodynamicist, Bell Aircraft Corp. (Buffalo).

Ross, William M., Jr., Aerodynamics Engr., Temco Aircraft Co.

Schulthess, Heiner P., Tech. Rep., SwissAir Transportation Co.

Smith, Lawrence F., M.S. in Ae.E., Aero. Engr., GS-11, Engrg. Requirements Branch, Oklahoma City Air Material Area (Tinker AFB).

Winborn, Byron R., Jr., B.S. in M.E., Mgr., Product Planning, General Electric Co. (Cincinnati).

Zabinsky, Joseph M., M.S. in Ae.E., Proj. Aerodynamicist, Bell Aircraft Corp.

Elected to Associate Grade

Abdelsalam, Adel, B.S. in M.E., Struct. Engr., Rohr Aircraft Co.

Beach, Earl C., Jr., B.S. in Ae.E., Test Proj. Engr., Data Analysis Dept., Southern California Cooperative Wind Tunnel.

Bonneh, Benjamin B., Lt. Col., Israeli AF; Mgr., Lod Airport (Jerusalem).

Brown, William P., M.S. in Civil Engrg., Stress Analyst, Boeing Airplane Co. (Seattle).

Campbell, Edward J., Sales Engr., Meletron Corp.

Cornwell, John M., Design Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

DeBiasi, Victor, B.S. in Ae.E., Systems Editor, *Aviation Age* Magazine.

Ellis, William C., Design Engr., Convair Div. (San Diego), General Dynamics Corp.

Feast, William E., Flight Operations Inspector, U.S. Dept. of Commerce.

Fenaughty, Ronald R., B.S. in M.E., Analytical Engr., Turbomotor Div., Curtiss-Wright Corp.

Folwell, Philip A., Design Engr., Convair Div. (San Diego), General Dynamics Corp.

Gardner, Charles J. T., Mgr. Information, Public Relations, Promotion, Vickers-Armstrongs (Aircraft), Ltd.

Kalogeris, John G., Test Engr., Convair Div. (San Diego), General Dynamics Corp.

Kent, Robert E., B.S. in Civil Engrg., Struct. Engr., Convair Div. (San Diego), General Dynamics Corp.

Lamberson, Dane G., B.S. in Ae.E., Aero. Engr., Vertol Aircraft Co.

Meller, Eliyahu, B.S. in Ae.E., Assoc. Aircraft Engr., Lockheed Aircraft Corp. (Marietta).

Merritt, Ward M., Jr., B.S. in M.E., Analytical Engr., Curtiss-Wright Corp.

Musgrave, Joseph S., B.S. in Chem. Engrg., Experimental Copilot, Boeing Airplane Co. (Wichita).

Peterson, Lyman L., B.S. in Arch. Engrg., Stress Analyst, Boeing Airplane Co. (Wichita).

Preston, Eric J., B.A. in Math., Postgraduate Trainee, Vickers-Armstrongs (Aircraft), Ltd. (Weybridge).

Schlemmer, Norman C., B.S. in Civil Engrg., Stress Analyst, Hayes Aircraft Corp.

Siciliano, Thomas A., B.A. in Math., Assoc. Engr., Northrop Aircraft, Inc. (Hawthorne).

Strasser, Gabor, B.S. in Civil Engrg., Struct. Research Engr., Bell Aircraft Corp. (Buffalo).

Trexel, John E., B.S. in M.E., Flight Test Engr., Convair Div., (San Diego), General Dynamics Corp.

Walker, David J., Liaison Engr., Aeronca Manufacturing Corp.

Young, Joseph B., Stress Engr., Avro Aircraft, Ltd. (Malton).

Transferred to Associate Grade

Anderson, William J., B.S. in Ae.E., Student, Iowa State College.

Bielefeld, Gilbert E., Jr. Engr., Design, Horkey Associates.

Baum, Howard R., B.S. in Ae.E., Research Asst., Aerodynamic Lab., Polytechnic Institute of Brooklyn.

Carlin, Raymond F., Jr., B.S. in Ae.E., Jr. Engr., Vertol Aircraft Corp.

Davis, Andrew V., B.S. in M.E., Graduate Asst., Stevens Institute of Technology.

Dennon, Jack D., B.S. in M.E., Engr., Rocketdyne Div., North American Aviation, Inc. (Canoga Park).

Dubrow, Alvin L., Engr., Tavco, Inc.

Evans, Frederick K., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (Santa Monica).

Ferriter, Patrick J., B.S. in Ae.E., Officer Candidate, USNR (Newport).

Fridsma, Gerard, B.S. in M.E., Proj. Engr., Experimental Towing Tank, Stevens Institute of Technology.

Geide, Richard F., B.S. in Ae.E., Design & Devel. Engr., Cessna Aircraft Co. (Wichita).

Haney, William S., Jr., B.S. in Ae.E., Assoc. Engr., Missiles Div., Douglas Aircraft Co., Inc. (Santa Monica).

Hawwa, Loutf M., B.S. in Ae.E., Asst. Proj. Engr., Mississippi State College.

Himebough, Willard D., B.S. in Ae.E., Assoc. Engr., Douglas Aircraft Co., Inc. (El Segundo).

Holt, Ira T., Staff Aide, Sandia Corp.

Hughson, Robert K., B.S. in Ae.E., Lt., USAF; Pilot in Training.

Kelley, Albert J., Sc.D. in Ae.E., Systems Engr., Guided Missiles, Navy Dept., Bureau of Aeronautics.

Kennet, Hiam, M.S. in Ae.E., Research Engr., Massachusetts Institute of Technology.

Kerr, Kenneth P., B.S. in Ae.E., Engr. (Aerodynamics), Lockheed Aircraft Corp. (Sunnyvale).

Ketchum, William J., Assoc. Engr., Convair Div. (Astronautics, San Diego), General Dynamics Corp.

Kinsel, Thomas L., B.S. in Ae.E., Assoc. Engr., Marquardt Aircraft Co.

Krol, J. Gregory, B.S. in Ae.E., Student, Parks College of Aeronautics.

Kruizenga, Garrett W., B.S. in Ae.E., Student, Tri-State College.

Kuhn, Alfred, B.S. in Ae.E., Power Plant Engr., Curtiss-Wright Corp. (Woodridge).

Lampert, Sidney, Dynamics Engr., Radioplane Co., Div. of Northrop Aircraft, Inc.

Leach, Rodman N., Test Engr., Sandia Corp.

McCrary, Emmet K., B.S. in Ae.E., Design Engr., Rocketdyne Div., North American Aviation, Inc. (Canoga Park).

Mulquin, James J., B.S., Student, Catholic Univ. of America.

Neuman, Dennis F., B.S. in M.E., Aerodynamics Engr., North American Aviation, Inc. (Columbus).

Olivas, Robert J., B.S. in Ae.E., Assoc. Engr. (Aerodynamics), Douglas Aircraft Co., Inc. (Long Beach).

Polski, Alfred L., B.S. in Ae.E., Aerodynamics Engr., North American Aviation, Inc. (Inglewood).

Roth, Henry A., Jr., Test Engr., Northrop Aircraft, Inc. (Hawthorne).

Sevigny, Eugene G., B.S. in Ae.E., Asst. Research Engr., Aero. Lab., Polytechnic Institute of Brooklyn.

Spring, Donald J., B.S. in Ae.E., Aerodynamics Engr., Convair Div. (Ft. Worth), General Dynamics Corp.

Theon, John S., B.S. in Ae.E., Aerodynamicist, Douglas Aircraft Co., Inc. (Santa Monica).

Wecker, Myron S., B.S. in Ae.E., Student, Cornell Univ.

Weir, Robert H., B.S. in Ae.E., Aircraft Maint. Officer, USAF (Pinecastle AFB).

Werner, Mark P., B.S. in Ae.E., Assoc. Engr., Convair Div. (San Diego), General Dynamics Corp.

White, W. Allen, Jr., Student, Univ. of Tulsa.

Witt, William W., B.S. in Ae.E., Engr., United Air Lines, Inc. (San Francisco).

Wosser, Joseph L., Jr., M.S. in Ae.E., Major, USMC; Pilot & Aero. Engr., USMC (Washington).

▲ ▲ ▲

Helicopter Forum

(Continued from page 27)

search, Cornell University; "Stability and Control of Propeller-Driven Transport VTOL Airplanes" by Robert H. Kirby, Langley Aeronautical Laboratory, NACA.

Theory and Test: "Determination of Flapwise Load Distribution on a Rotor Blade From Measured Strain and Rotor Data" by Herbert Somerson, Piasecki Aircraft Corporation; "On a Type of Low-Advance-Ratio Blade Flapping Instability of Three-or-More-Bladed Rotors Without Drag Hinges" by K. H. Hohenemser, McDonnell; "Theoretical and Experimental Study of the Coupled Flap Bending and Torsion Aeroelastic Vibrations of a Helicopter Rotor Blade" by Peter F. Leone, Vertol; "A Parametric Analysis Method for Rotor Blade Structural Design" by Alex Berman, Kaman Aircraft Corporation; "Physical Interpretation of Helicopter Chordwise Vibrations" by William B. Gevarter, Hiller.

Operations and Navigation: "Helicopter Transport Operations in the North" by Lt. Col. Oscar N. Tibbetts, C.O., 22nd. Helicopter Squadron, 6614th Air Transport Group Medium, USAF; "Application of the Decca Navigation System as an Approach and Landing Aid" by H. W. Mitchell, Bell; "The French Army Helicopter Operation in Algeria" by T. R. Pierpoint and L. J. Geier, Vertol.

ERRATUM

In the July, 1957, issue of the *Review*, the photographs, excluding the captions, at the top of pages 27 and 29 should be transposed.—*Ed.*

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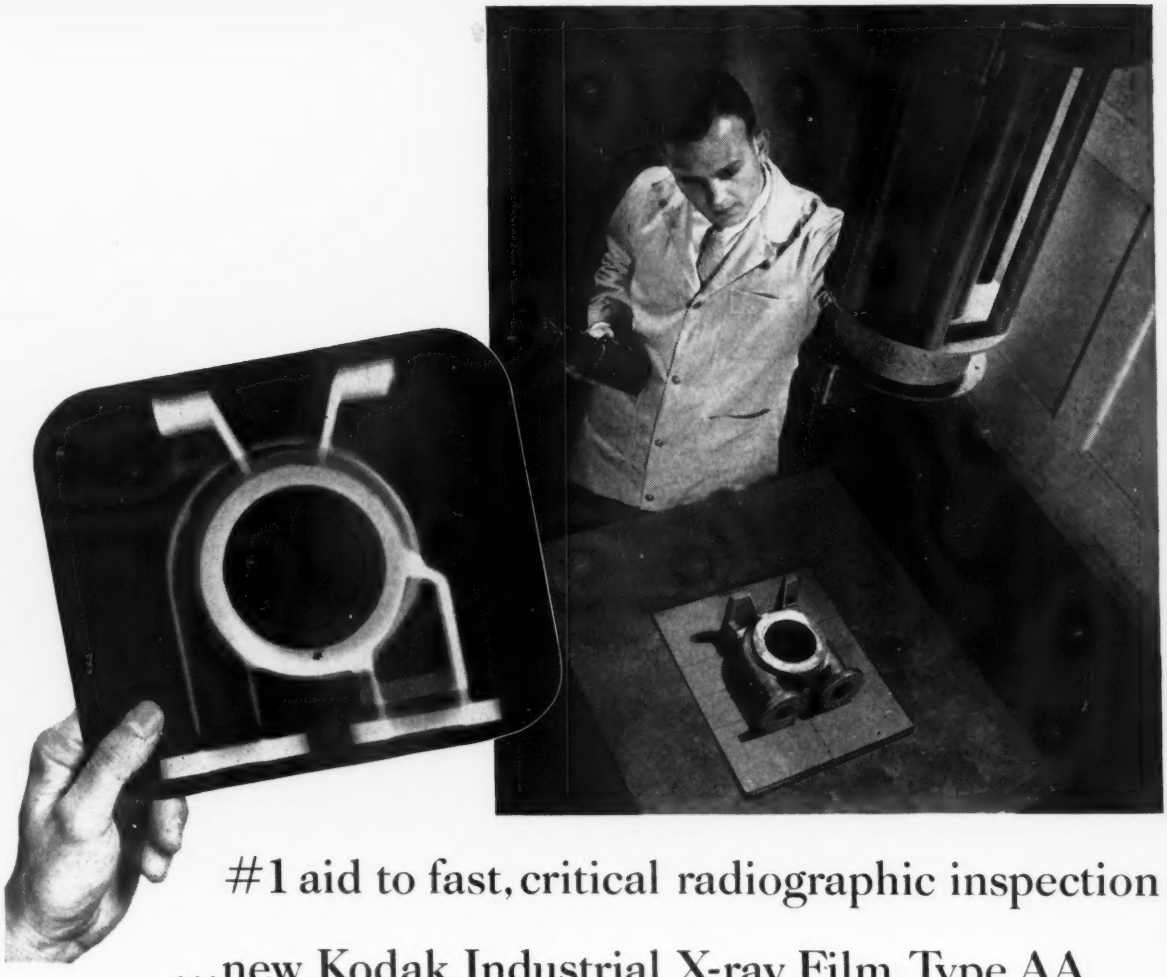

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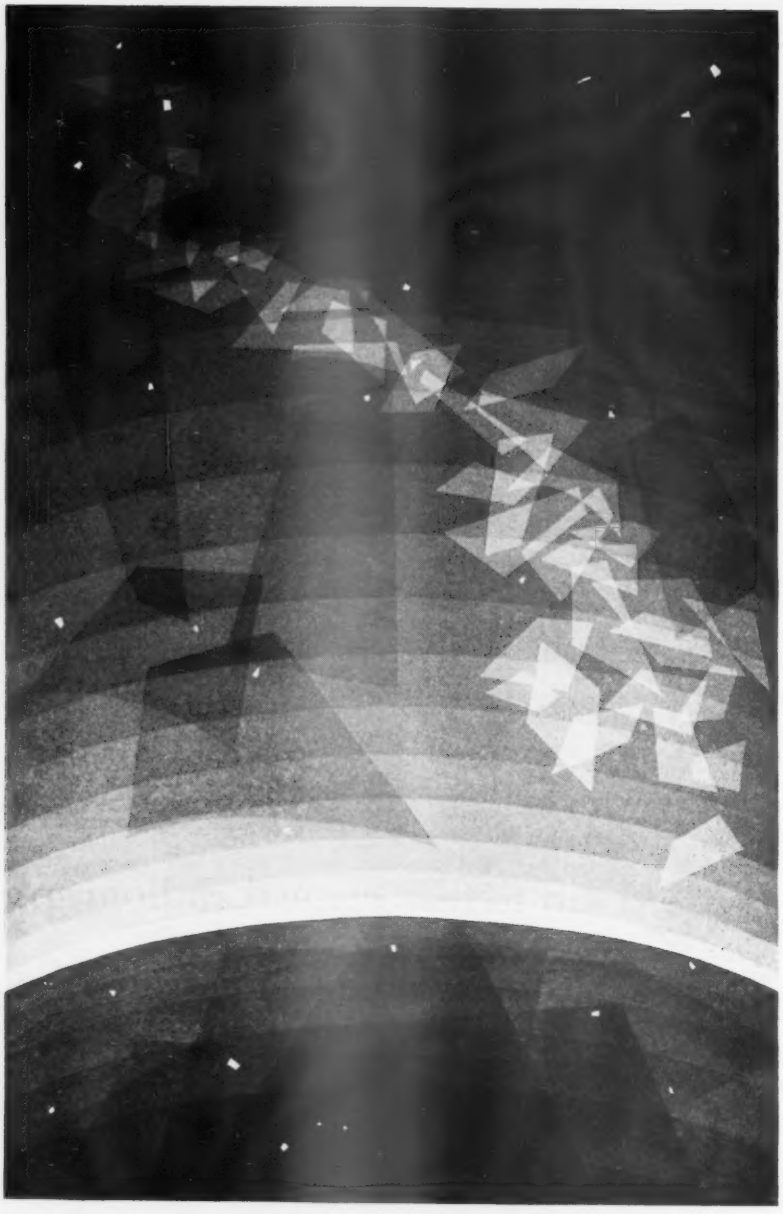

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Acoustics, Sound, & Noise

Propagation of Sound in Inhomogeneous Media (Survey). L. M. Brekhovskikh. (*2nd Internatl. Acoustics Cong., Cambridge, Mass., June 21, 1956.*) *Soviet Physics - Acoustics*, No. 3, 1957, pp. 247–255. 13 refs. Translation. Discussion of sound propagation for two different mediums—one with regular inhomogeneities of a laminar character and the other with inhomogeneities of a random character.

Aerodynamics

Charts Offer "First Pass" Design Check. Sherman V. Brunk. *Av. Week*, May 20, 1957, pp. 78, 79, 83, 85, 86–95 ff. Presentation of eight design charts to aid in preliminary design work by providing a method for reducing the time and effort required to analyze large numbers of new designs.

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Similar Solutions for the Compressible Laminar Boundary Layer with Heat Transfer and Pressure Gradient. Clarence B. Cohen and Eli Reshotko. *U.S., NACA Rep. 1293*, 1956. 38 pp. 27 refs. Supt. of Doc., Wash., $0.40. Application of Stewartson's transformations to compressible boundary-layer equations, resulting in a set of ordinary nonlinear differential equations which, in turn, are transformed to an integral system with the velocity ratio as the independent variable.

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Lift Hysteresis at Stall as an Unsteady Boundary-Layer Phenomenon. Franklin K. Moore. *U.S., NACA Rep. 1291*, 1956. 10 pp. Supt. of Doc., Wash., $0.20. Approximate analysis for a 6:1 elliptic airfoil at the angle of attack for maximum lift. The assumption of small perturbations from maximum lift is made, permitting neglect of distributed vorticity in the wake.

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Diffusion from an Infinite Line Source Lying Perpendicular to the Mean Wind Velocity of a Turbulent Flow. T. S. Walters. *Quart. J. Mech. & Appl. Math.*, May, 1957, pp. 214–219. Derivation of a solution for the general case of an elevated source.

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Sears Function in Unsteady Flows. Hsuan Yeh. *J. Aero. Sci.*, July, 1957, pp. 546, 547. Table giving corrected and extended values for the Sears function.

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Lehren einer fünfzigjährigen Strömungsforschung. Albert Bentz. *ZFW*, Apr., 1957, pp. 97–105. 15 refs. In German. Historical review of the developments in aerodynamic theory.

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Cascade Investigation of a Related Series of 6-Percent-Thick Guide-Vane Profiles and Design Charts. James C. Dunavant. *U.S., NACA TN 3959*, May, 1957. 48 pp. 12 refs. Description of a new blade series designed to operate at near choking inlet Mach Numbers and to achieve near maximum critical Mach Numbers by using high aerodynamic load-

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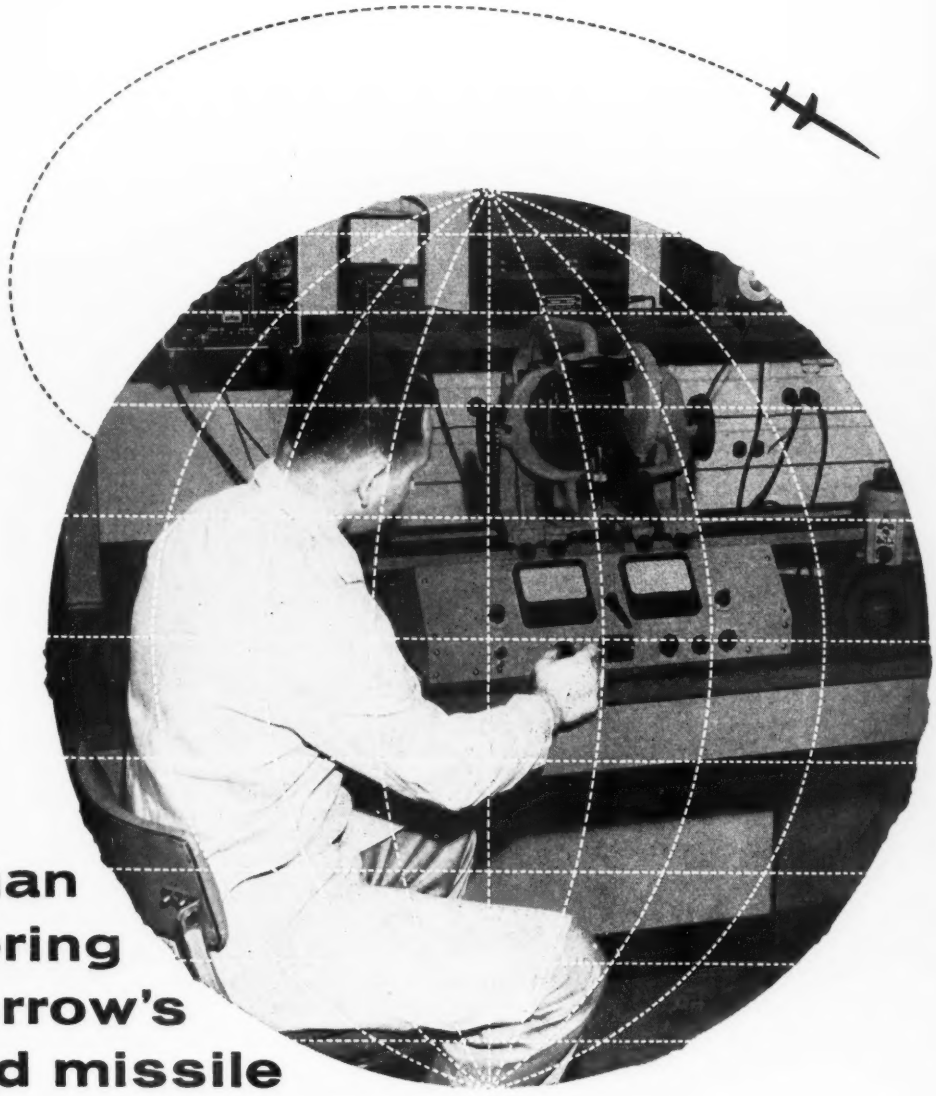

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Inlets for Supersonic Aircraft. William Stubbs. *SAE J.*, May, 1957, pp. 34, 35. Abridged. Discussion of the aerodynamic principles and the operational mode of variable-geometry intakes.

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How to Improve Systems Engineering. John W. Warfield. *Aero. Eng. Rev.*, July, 1957, pp. 50, 51. Discussion of possible solutions for certain multidiscipline, communication, and coordination problems.

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Aerodynamic and Economic Characteristics of Turboprop Air-Line Transport Systems. Ralph Allen. *Aero. Eng. Rev.*, July, 1957, pp. 55–58. Applications of a system analysis approach to turboprop transport systems, taking into account airplane performance, economics of the system, and employment of the airplane. Velocity, range, time delay, and useful load ratio are discussed with respect to their effects on profit margin.

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Supersonic Aircraft; Force Centralization of Design and Procurement Authority. Frank W. Davis. *SAE J.*, May, 1957, pp. 19–21. Abridged. Discussion of the design of the B-58 in terms of the weapon systems concept. The roles of the prime contractors, the subsystem contractors, and the USAF monitoring agencies are examined.

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Caravelle Structure Designed for Good Fatigue Strength. Paul Vallat. (*2nd European Aero. Congr., Scheveningen, Sept., 1956.*) *Av. Age*, May, 1957, pp. 66, 67, 68–73 ff. Discussion of wing and fuselage design characteristics which resist fatigue failure.

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T2J Designed as Primary-Through-Advanced Trainer. Erwin J. Bulban. *Av. Week*, May 13, 1957, pp. 52, 53, 55, 56, 59 ff. Description of North American Aviation's new training aircraft in terms of its design concept and its use of stock items.

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Designing Fatigue-Resistant Structures For Pressurised Transports. Paul Vallat. *Aircraft* (Australia), Apr., 1957, pp. 28–32, 56.

Crusader; An Analysis of Chance Vought's Supersonic Naval Fighter. *Flight*, May 24, 1957, pp. 691–696, cuta-

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Mixed-Power Intercepter; An Introduction to the Saunders-Roe Rocket/Turbojet Prototype. *Flight*, May 24, 1957, pp. 697–700.

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The Jet That Lives on the Water. *CEC Recordings*, May-June, 1957, pp. 6–8. Description of the instrumentation and MilliSADIC engine-testing system of the Navy's multijet seaplane, the XP6M-1 Sea Master.

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Effect of Interaction on Landing-Gear Behavior and Dynamic Loads in a Flexible Airplane Structure. Francis E. Cook and Benjamin Milwitzky. *U.S., NACA Rep. 1278*, 1956. 30 pp. 13 refs. Supt. of Doc., Wash., $0.30. Analysis of the interaction of the landing gear and structure on the behavior of the landing gear and the loads in the structure, treated by using the equations of motion of the airplane and the landing gear as a coupled system.

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The Speed of Transport Aircraft—An Analysis of Transatlantic Requirements. E. T. House. *Shell Av. News*, Apr., 1957, pp. 8–11. Discussion of optimum speed for air-line aircraft in terms of achieving the most economical overall trip time, timetable, and fleet utilization.

Development of Infra-Red Defrosting for Aircraft Canopies. Leon Bennett, Wm. D. Murrary, and H. K. Work. *USAF WADC TR 53-115 [AD 118065]*, Mar., 1957. 79 pp. 11 refs. Analysis of infrared defrosting in terms of power required, sources, materials, canopy temperatures, automatic temperature regulation, visible light output, efficiency, and other factors. A final design is prepared for the B-47B, and details are presented.

Fog in the Cockpit. J. E. Slatky. *CEC Recordings*, May-June, 1957, pp. 12–14. Solution of fog problems in pilot enclosures by high-vacuum techniques.

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Effect of Exponential Type Control Lags on the Speed and Accuracy of Positioning a Visual Indicator. Melvin J. Warrick. *USAF WADC TN 55-348 [AD 99520]*, June, 1955. 12 pp. Investigation to determine what effect controller-system lags have on the human operator's ability to position a visual indicator rapidly and accurately.

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Engineering Problems. Martin L. Klein, Frank K. Williams, and Harry C. Morgan. *Instruments & Automation*, May, 1957, pp. 889, 890. Evaluation of a polynomial using an eight-step program in a general-purpose digital computer.

An Introduction to Automatic Electronic Computing for Engineering Calculations. B. J. Kaganov. *Can. Aero. J.*, May, 1957, pp. 155–160.

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Digital Printer Boosts Readout Time. H. W. Gettings. *Electronics*, June 1, 1957, pp. 182–185.

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A Scaling Technique Designed to Give Approximations to Factor Scales. Dorothy M. Knoell and Roy A. DeGaugh. *USAF PTRC RR TN 57-21 [AD 098924]*, Feb., 1957. 18 pp.

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The Influence of Force and Amplitude Cues on Learning and Performance in a Complex Tracking Task. George E. Briggs, Harry P. Bahrick, and Paul M. Fitts. *USAF PTRC RR TN 57-33 [AD 098938]*, Mar., 1957, 12 pp. 10 refs. Examination of the effects of training in a F-86D simulator with a control column in which the force and/or the amplitude cues are reduced by a factor of four as compared to the levels of these cues present in the operational aircraft at an airspeed of 500 kt. and at an altitude of 35,000 ft.

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The Application of an Analog Computer to the Measurement of Process Dynamics. P. E. A. Cowley. (*ASME-ISA Conf., New York, Sept. 17–21, 1956, Paper 56-IRD-20.*) *Trans. ASME*, May, 1957, pp. 823–832. Description of the usual method for obtaining frequency-response measurements and of two techniques employing analog computers for data reduction. Results of laboratory measurements on a dummy process and of field measurements on a real process are given to demonstrate the advantages of the latter techniques over the former method. Further benefits to be derived from the use of digital computers are indicated.

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How to Pick Cooling Systems for Electronics at Mach 1–3. C. F. Johnson. *Av. Age*, May, 1957, pp. 122, 123, 124–128 ff. Review of four basic cooling methods and their respective advantages. Methods include free-convection air cooling, forced-air cooling, liquid cooling, and evaporative cooling.

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Investigation on Carbon Pile Regulator Type 79, in Relation to Generator Drive Quill Shaft Failure on Canberra Aircraft. T. S. Law and R. L. A. McKenzie. *Gt. Brit., RAE TN El. 134*, Feb., 1957. 22 pp. Experimental investigation to determine the stability of the automatic voltage-regulated d.c. power system with Type 512 generator and Type 79 regulator. Frequency-response results and the effects on static voltage regulation with change in the composition of the carbon pile are given.

Transistor Audio Amplifiers and Oscillators. Hugo Korn. *Motorola Newsgram*, Mar.-Apr., 1957, pp. 28, 29. Discussion of coupling-circuit design and its associated matching problems.

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High-Reliability Transistorized Counter. H. C. Chisholm. *Electronics*, June 1, 1957, pp. 171–173. Description of a system in which cascaded silicon-junction transistor binary stages energize neon-lamp indicators for a digital frequency

(*Continued on page 132*)

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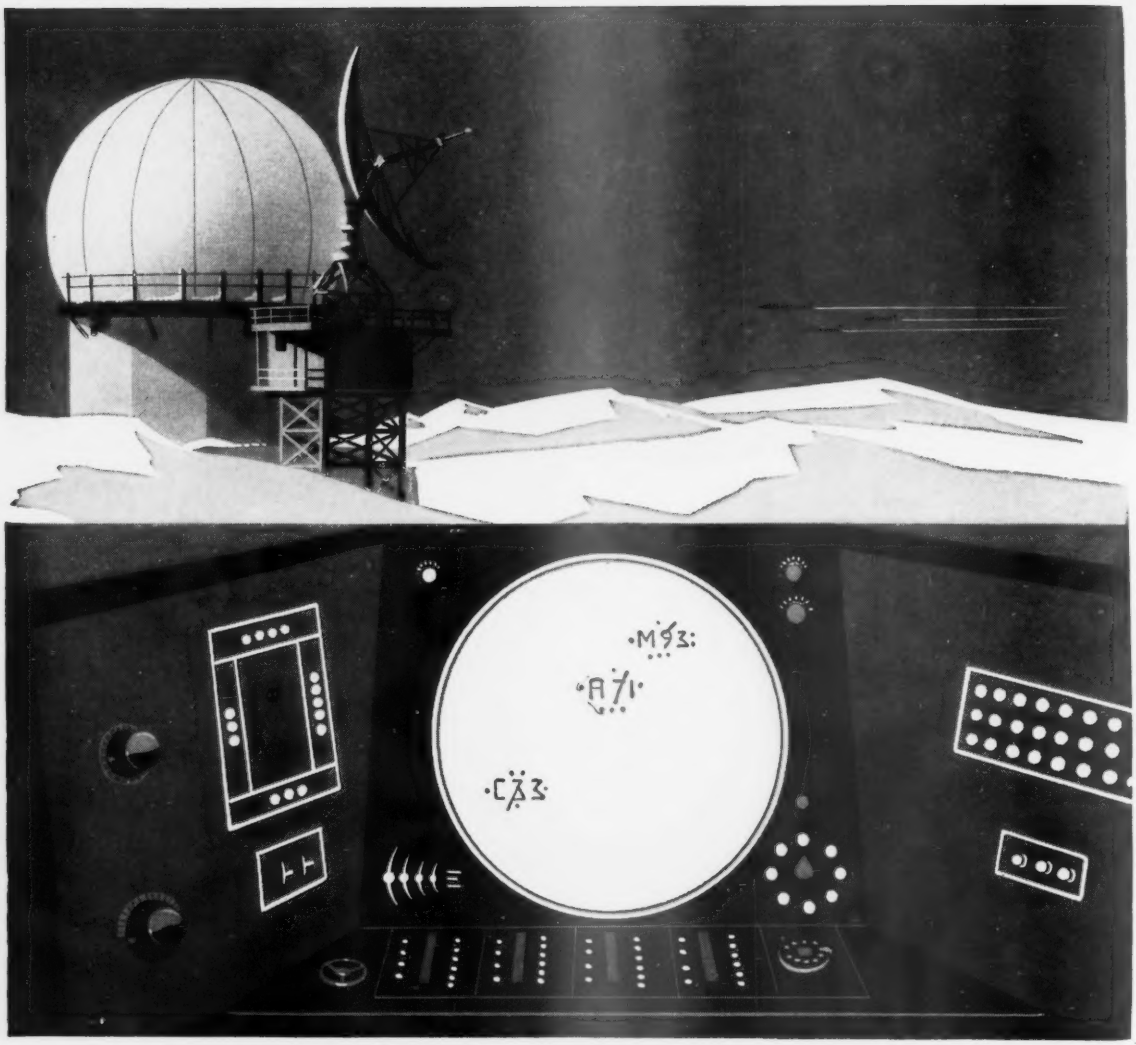

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ACOUSTICS, SOUND, & NOISE

EFFECT OF STANDING TRANSVERSE ACOUSTIC OSCILLATIONS ON FUEL-OXIDANT MIXING IN CYLINDRICAL COMBUSTION CHAMBERS. W. R. Mickelsen. US, NACA TN 3983, May, 1957. 49 pp. 10 refs. Analysis for acoustic conditions commonly found in screeching and screaming combustors. Transverse acoustic fields in cylindrical ducts are described in terms of pressure fluctuation, particle velocity, and oscillation frequency. The effect of such acoustic fields on the fuel-oxidant mixing downstream from point sources of injection is treated theoretically to obtain expressions relating the fuel-oxidant ratio to the parameters of the stream and the acoustic field. Numerical solutions of these relations are obtained to illustrate the effect of sound-pressure level, stream velocity, and turbulence level. A number of possible mechanisms contributing to screech and scream in various combustor configurations are proposed and methods are suggested for their control.

AERODYNAMICS

THEORETICAL LOAD DISTRIBUTIONS ON FIN-BODY-TAILPLANE ARRANGEMENTS IN A SIDE-WIND. J. Weber and A. C. Hawk. Gt. Brit., ARC R&M 2992, 1957. 58 pp. 14 refs. BIS, New York, $3.06. Development of a theory for calculating the distributions of sideforce and lift on fin-fuselage-tailplane arrangements in a side-wind, but with the tailplane set at zero incidence. Analysis is limited to incompressible flow and is further simplified by assuming that the geometrical arrangement is in each case such as to give constant induced sidewash. The results, which can be extended to other arrangements and to compressible subcritical flow, are required for stability and stressing analyses. The main functions in the calculation are presented for representative cases in the form of tables and charts.

Aerothermodynamics

COMPRESSIBLE LAMINAR BOUNDARY LAYER OVER A YAWED INFINITE CYLINDER WITH HEAT TRANSFER AND ARBITRARY PRANDTL NUMBER. Appendix A, B - SOLUTION OF ORDINARY DIFFERENTIAL EQUATIONS. Appendix C - ASYMPTOTIC SOLUTION. Appendix D - STAGNATION-LINE RECOVERY FACTOR FOR YAWED CYLINDER. Eli Reshotko and I. E. Beckwith. US, NACA TN 3986, June, 1957. 86 pp. 29 refs. Derivation of a set of three simultaneous ordinary differential equations by use of the Stewartson transformation and a linear viscosity-temperature relation. The equations are solved for stagnation-line flow for surface temperature from zero to twice the free stream stagnation temperature and for a wide range of yaw angle and free-stream Mach Number. The results show that the effect of yaw on heat-transfer coefficient at the stagnation line depends markedly on the free-stream Mach Number.

Boundary Layer

THE THREE-DIMENSIONAL BOUNDARY-LAYER EQUATIONS AND SOME POWER SERIES SOLUTIONS. L. C. Squire. Gt. Brit., ARC R&M 3006, 1957. 17 pp. BIS, New York, $0.99. Derivation of boundary-layer equations using a general coordinate system based on those used by Howarth in his previous derivation. Various theorems hitherto only proved in more restrictive systems are extended to this general system. The particular case of streamlines of zero geodesic curvature is investigated and a solution of such flow found by a power series method. Finally Howarth's stagnation-point solution is extended to second-order terms by numerical investigation.

A SIMPLIFIED METHOD FOR THE CALCULATION OF THREE-DIMENSIONAL LAMINAR BOUNDARY LAYERS. J. A. Zaat. Netherlands, NLL Rep. F.184, Apr., 1956. 13 pp. Derivation of an approximation of the momentum equations for three-dimensional laminar boundary layers by two total differential equations of the first order. It is assumed that the boundary-layer velocities in the direction perpendicular to the local free flow are small compared with those in the direction parallel to the flow. The boundary-layer quantities in the

direction of the local free flow are calculated by neglecting the boundary-layer crossflow, but taking into account the three-dimensional character of the potential flow. The crossflow is calculated by using results for the main flow which lead to an integral equation. This method is applied to flow about a yawed ellipsoid at zero incidence, and the results agree with those obtained from the complete momentum equations.

POHLHAUSEN-TYPE, LAMINAR, INCOMPRESSIBLE BOUNDARY LAYER SOLUTIONS. Kenneth R. Cramer. USAF WADC TR 56-569 [AD 118114], Dec., 1956. 35 pp. 32 refs. Review and comparison of existing Pohlhausen-type laminar, incompressible boundary-layer solutions. An integral-type solution is developed on the basis of Timman's velocity profiles, and the accuracy is determined by comparing the results obtained from example problems, exact solutions, and experimental results. It is concluded that either the above method or Thwaites' solution should be employed for determining the boundary-layer parameters for flow over arbitrarily shaped bodies.

EFFECT OF YAW ON BOUNDARY LAYERS AT HIGH SPEEDS. Appendix A - EQUATIONS OF MOTION AND THEIR TRANSFORMATIONS (COMPRESSIBLE CASE). Appendix B - INTEGRATION METHOD. H. G. Lew and J. B. Fanucci. Penn. State U. Dept. Aero. Eng. TR 9 (AFOSR TN 57-221) [AD 126519], Nov., 1956. 51 pp. 12 refs. Theoretical investigation of the flow over yawed infinite wings in a compressible fluid with heat transfer at the surface. Results for wall shear, heat-transfer coefficient, and the modified Reynolds analogy variations with sweepback are compared using, wherever possible, the expansions in the enthalpy function at the wall or surface of the body (S_o) and a sweepback parameter. It is shown that, for the usual range of these variables, the derived method is sufficient for most purposes. Results for the stagnation-point flow indicate that the heat-transfer coefficient is decreased considerably by sweepback. When the sweepback parameter equals zero, the two-dimensional results compare favorably with the more exact calculations of Cohen and Reshotko, even to the extreme values $S_o = \pm 1$.

EFFECT OF YAW ON THE COMPRESSIBLE LAMINAR BOUNDARY LAYER. J. Tinkler. Gt. Brit., ARC R&M 3005, 1957. 14 pp. BIS, New York, $0.81. Transformation of equations governing the laminar compressible boundary layer on a yawed body of infinite span to give three nondimensional equations defining two velocity components and the enthalpy. Assuming that the Prandtl Number is unity and that there is zero heat transfer, a relation is obtained between the stream Mach Number and the angle of yaw for flows which give the same boundary-layer equations. The further assumption of viscosity proportional to the absolute temperature is made and similar solutions are found to be given by a family of surface Mach Number distributions normal to the leading edge.

ESTIMATION OF COMPRESSIBLE BOUNDARY-LAYER GROWTH OVER INSULATED SURFACES WITH PRESSURE GRADIENT. Appendix---TRANSFORMATION OF MOMENTUM AND ENERGY EQUATIONS. Gerald W. Englert. U.S., NACA TN 4022, June, 1957. 35 pp. 27 refs. Extension of the incompressible boundary-layer theory of Truckenbrodt using a modified Stewartson-type transformation. The variation of turbulent shear stresses with Mach Number of the bounding potential stream is considered using the reference-temperature method of Eckert. The procedure developed is applicable to two-dimensional and axisymmetric laminar and turbulent boundary layers, and accounts for the pressure gradient along the wall, for both compressible and incompressible flow.

ON THE CALCULATION OF STEADY LAMINAR BOUNDARY LAYER FLOWS WITH CONTINUOUS SUCTION. Henry Görtler. J. Math. & Mech., May, 1957, pp. 323-340. 10 refs. Presentation of an exact solution, in the form of an infinite series, for the boundary-layer equations of plane and steady laminar boundary-layer flow of an incompressible viscous fluid around a cylinder, in the general case of arbitrary outer velocity distribution $U(x)$ and arbitrary suction velocity distribution $v_o(x)$ along the wall. A method is described for deriving the numerical evaluation of such flows from the series. This method is shown to be so simple that the amount of work involved in calculating the boundary layer flow for any given $U(x)$ and $v_o(x)$ is comparable with that of the nonrigorous and unreliable parameter methods of the momentum-integral type.

PERFORATED SHEETS AS THE POROUS MATERIAL FOR A SUCTION-FLAP APPLICATION. R. E. Dannenberg, J. A. Weiberg, and B. J. Gambucci. US, NACA TN 4038, May, 1957. 36 pp. Investigation on a two-dimensional model of an NACA 0006 airfoil with area suction applied on the upper surface near the hinge line of a 0.3-chord plain trailing-edge flap. Measurements are made of both the pressure and the suction velocity distributions over the surface of the porous region for each permeability arrangement tested, over a range of suction flow extending from no flow to a value well above that required for separation control over the flap. Further information on the effects of hole size and spacing is provided by using perforated sheets with a resistance backing to control the inflow distribution. Limits are indicated for the hole size and the hole spacing suitable for the porous region on a suction flap.

Control Surfaces

THE AERODYNAMIC ACTION OF TRIANGULAR HORN-BALANCED CONTROL SURFACES ON THE SUPERSONIC DELTA WING. Derek Naylor. J. Aero. Sci., Aug., 1957, pp. 574-578. Determination of the pressure distribution on the basis of linearized theory for a delta wing in the region of influence of a deflected flap type of control with a triangular horn balance. General formulas for the control hinge-moment increment are calculated to estimate the effectiveness of an aerodynamic bal-

ance of the type considered, and corresponding formulas for the increment in the lift are also developed. The final expressions for the increments are represented graphically as functions of a delta-wing parameter based on the leading-edge sweepback and the free-stream Mach angle, and a geometrical parameter determined by the control surface configuration.

Fluid Mechanics & Aerodynamic Theory

ON THE THEORY OF BINARY FLUID MIXTURES. F. J. Pearson and G. S. Rushbrooke. Proc. Royal Soc. (Edinburgh), Sect. A, 1955-57, pp. 305-317. 18 refs. Derivation of a compressibility equation for binary mixtures. Based on an equivalence of expressions for the mean-square fluctuation in the total number of systems, the derivation is presented in terms of thermodynamic and radial distribution functions. The problem of evaluating the corresponding radial distribution functions by means of X-ray or optical scattering is solved by a concentration correlation function from observations of critical opalescence.

SOME ASPECTS OF THREE-DIMENSIONAL CAVITY FLOW. A. J. Taylor-Russell. J. RAeS, May, 1957, pp. 345-352. Study of the wake-flow region of an equilateral triangular plate at large angles of incidence with emphasis on the region of recirculation. Data is presented for some measurements of force coefficients, static pressure, and mean velocity. An attempt is made to explain why the recirculatory flow is found only at angles of incidence greater than 35°.

ON THE HYDRODYNAMIC STABILITY OF TWO VISCOUS INCOMPRESSIBLE FLUIDS IN PARALLEL UNIFORM SHEARING MOTION. Saul Feldman. J. Fluid Mech., June, 1957, pp. 343-370. 20 refs. Analysis based on small-disturbance theory which leads to a characteristic value problem in a system of two linear ordinary differential equations. The essential dimensionless parameters that appear in the present problem are the viscosity ratio m, the density ratio r, the Froude Number F, and the Weber Number W. The results are presented graphically for most fluid combinations of possible interest. The neutral stability curve is single-looped, as in the boundary-layer case. General agreement between theoretical and experimental values exists for all critical quantities except the Reynolds Number. Gravity and surface tension are found to have a destabilizing effect on the flow. The linear velocity profile of two adjacent fluids with the same viscosity, but different densities, is shown to be unstable for high Reynolds Numbers.

AN ELECTRONIC ANALOGUE FOR SUPERSONIC FLOW. L. S. G. Kovásznay. J. Fluid Mech., June, 1957, pp. 383-396. Presentation of an analog method for solving certain quasi-linear hyperbolic partial differential equations. The characteristic lines are formed by scanning electronically the screen of a cathode-ray tube. The boundary conditions are introduced in the form of an opaque mask. The solution appears as a picture on the screen of a second cathode-ray tube.

ON FLOW OF ELECTRICALLY CONDUCTING FLUIDS OVER A FLAT PLATE IN THE PRESENCE OF A TRANSVERSE MAGNETIC FIELD. V. J. Rossow. US, NACA TN 3971, May, 1957. 54 pp. 41 refs. Investigation of the use of a magnetic field to control the motion of electrically conducting fluids. The boundary-layer solutions are found for flow over a flat plate when the magnetic field is fixed relative to the plate or to the fluid. The equations are integrated numerically for the effect of the transverse magnetic field on the velocity and temperature profiles and, hence, the skin friction and rate of heat transfer. Results indicate that the skin friction and the heat-transfer rate are reduced when the transverse magnetic field is fixed relative to the plate, and increased when fixed relative to the fluid. The total drag is increased in all the cases studied.

ON THE UNSTEADY MOTION OF A VISCOUS FLUID PAST A SEMI-INFINITE FLAT PLATE. G. F. Carrier and R. C. DiPrima. J. Math. & Phys., Jan., 1957, pp. 359-383. 11 refs. ONR-supported analysis based on a system of equations derived by a modified Oseen linearization of the equation of motion. It is found that the flow field consists of the sum of the mean flow and an oscillatory motion. The phase advance in the oscillatory motion is $\pi/8$ at the leading edge and increases monotonically to $\pi/4$. The result is a shear-wave type solution and corresponds to an infinite lamina performing harmonic oscillations in a viscous fluid.

ON THE FLOW OVER A FINITE WEDGE IN THE LOWER TRANSONIC REGION. Hideo Yoshihara. USAF WADC TR 56-444 [AD 110428], June, 1956. 27 pp. 18 refs. Analysis of flow over a wedge at zero incidence for the lower transonic region by means of transonic small-perturbation method in the hodograph plane. The problem consists of a transonic boundary-value problem and a supersonic initial-value problem. The essential difficulty results from the fact that, in the transonic boundary-value problem, part of the subsonic boundary and the condition to be prescribed there depend on the solution of the supersonic initial-value problem, while the initial data for the latter must be obtained from the transonic boundary-value problem. The solution is an iterative one with the direct goal being the determination of the unknown subsonic boundary condition. In the resulting problem a special behavior of the solution is used to obtain convergence of the process.

AN EXPERIMENTAL INVESTIGATION OF THE PRESSURE ON A THIN FLAT PLATE AT HYPERSONIC SPEEDS. I. E. Vas. Princeton U. Dept. Aero. Eng. Rep. 377 (USAF WADC TN 57-104) [AD 118151], Mar., 1957. 20 pp. 20 refs. Test results which indicate that the pressure on a flat plate at hypersonic speeds depends upon the leading edge thickness. For large values of Reynolds Number, the inviscid effects predominate on the plate, the pressure depending on the Mach Number and the geometric parameter, x/t. For small Reynolds Numbers, the viscous effects predominate, the pressure depending upon the Mach Number, the geometric parameter, and the viscous parameter.

APPLICATION OF THE VARIATIONAL METHOD TO THE PROBLEM OF AXISYMMETRIC ROTATIONAL COMPRESSIBLE FLOW. Bohdan Krajewski. Arch. Mech. Stosowanej, No. 2, 1957, pp. 211-215. Description of a method for reducing the flow problem to a variational problem by introducing the stream function ψ and changing variables. It is shown that further considerations can be undertaken by one of the known methods, such as that of Ritz or Galerkin.

A SHOCK-EXPANSION THEORY APPLICABLE TO WINGS WITH ATTACHED SHOCK WAVES. L. M. Sheppard and K. D. Thomson. Gt. Brit., RAE TN Aero. 2493, Jan., 1957. 17 pp. 10 refs. Extension of shock-expansion theory to give a method for computing the surface pressure distribution on three-dimensional wings with shock waves attached to the edges. Although the extended method is derived for high Mach Numbers only, preliminary comparisons of its predictions with those of linearized theory and the one experiment available indicate that it can be applied at quite low Mach Numbers, provided that the wing edges are highly supersonic. Two simple illustrative examples are given.

ON THE STABILITY OF PLANE SHOCK WAVES. N. C. Freeman. J. Fluid Mech., June, 1957, pp. 397-411. Analysis of the decay of small perturbations on a plane shock wave propagating along a two-dimensional channel into a fluid at rest. An expression for the pressure distribution produced by the obstacles upon the shock wave is built up as an integral of a Fourier type. From this the shock shape is deduced and the decay of the perturbations obtained from an expansion (valid after the disturbances have been reflected many times between the walls) for the shock shape in a descending power of the distance traveled by the shock wave. It is shown that perturbations die out in an oscillatory manner, and that a Mach Number of maximum stability (1.15) exists, the disturbances to the shock wave decaying most rapidly at this Mach Number.

ONE-DIMENSIONAL SHOCK-MOTION OF A GAS WITH $\gamma = 3$, ENCLOSED BETWEEN FIXED WALLS. G. Kuerti and K. Faymon. J. Math. & Phys., Jan., 1957, pp. 384-393. ONR-supported analysis of the motion of the gas beyond the "breakdown point" - the point at which infinite gradients of velocity and pressure usually occur. In the example studied, the region-wise homentropic character of the flow subsists although the velocity is nonuniform in the two regions separated by the shock. A shock solution is found which makes it possible to calculate the successive shock reflections at the walls and the associated u and c (dimensionless particle and sound velocities, respectively) distributions for any time. Numerical results are given.

GENERALIZATION OF INTEGRAL RELATIONSHIPS WITH APPLICATIONS IN WING-BODY INTERFERENCE, WING THEORY, AND DIFFRACTION OF PULSES. Appendix A - INTEGRALS OF DISTURBANCE PRESSURE ON THE GROUND. Lu Ting. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 379 (AFOSR TN 57-159) [AD 126451], Apr., 1957. 44 pp. 15 refs. Proof of a theorem concerning the integrated properties of the linearized pressure distribution on a cylindrical surface in a supersonic stream when the normal velocity on the cylindrical surface is prescribed. The theorem is applied, without using Evvard's result, in the derivation for lift and drag of a rectangular wing with a constant zero-thickness profile in supersonic flight. A pressure integral theorem is obtained for the diffraction of a pulse or a weak shock over a rectangular notch. Its usefulness is demonstrated in reducing the work entailed in obtaining the mean pressure distribution along any depth inside the notch at different instants for various width-height ratios.

NONUNIFORMITIES IN SHOCK-TUBE FLOW DUE TO UNSTEADY-BOUNDARY-LAYER ACTION. Harold Mirels and W. H. Braun. US, NACA TN 4021, May, 1957. 45 pp. Evaluation for shock tubes in which the boundary layer is thin relative to the tube diameter and is either wholly laminar or wholly turbulent. The hot-gas region between the shock wave and the contact surface is considered. Both the axial distributions at any instant and the temporal distributions at any axial position within this region are found. Numerical computations are presented for an air-air shock tube. The analytical method used is an extension of the one previously developed by Mirels for finding the similarly caused flow perturbations immediately behind the shock wave in a shock tube. It is assumed that the boundary-layer action is equivalent to a one-dimensional distribution of mass sources and that the expansion wave has zero thickness.

CHARTS OF FLOW PROPERTIES BEHIND PLANE AND CONICAL SHOCK WAVES AT OUTER EDGE OF BOUNDARY LAYER. Reinhard Krause and J. L. Gordon. USAF HADC TN 57-5 [AD 113035], May, 1957. 25 pp. Graphs of the ratio of local to free stream conditions vs. free-stream Mach Number, plotted up to $M_\infty = 20$ for pressures, densities, velocities, Mach Number, and temperatures. Charts are based on a ratio of specific heats of $\gamma = 1.4$, except for the data for conical flow which are available only for $\gamma = 1.405$.

SPACE-TIME DOUBLE CORRELATIONS AND SPECTRA IN A TURBULENT BOUNDARY LAYER. A. J. Favre, J. J. Gaviglio, and R. Dumas. J. Fluid Mech., June, 1957, pp. 313-342. 15 refs. Experimental investigation on the turbulent boundary layer of a flat plate with zero pressure gradient. Transition is obtained either by increasing the preturbulence upstream of the plate by means of a grid, or by a series of emery-paper roughness elements beginning at the leading edge. The measurements are taken for the space-time double correlations, i.e., double velocity correlations with both spatial separation and time delay, from which isocorrelation lines for optimum delay can be drawn, and for the spectrum function - all for the longitudinal component of the velocity fluctuation.

Internal Flow

EXPERIMENTS AT LOW REYNOLDS NUMBERS. I - ISOLATED AIRFOILS. II - AXIAL FLOW TURBOMACHINE. Joseph Neustein. CIT Hydrodynamics & Mech. Eng. Lab. Rep. No. 6, Mar., 1957. 221 pp. 44 refs. Determination of pressure distributions for three types of airfoils in the Reynolds Number range between 5,000 and 200,000. Turbulence in the main stream, varied over a wide range, is found to be effective in sustaining relatively high lift for thick airfoils at Reynolds Numbers as low as 7,000. A sharp leading-edge plate-airfoil produces lift exceeding the potential-flow value for a flat plate. Investigation of the performance of a single-stage axial-flow turbomachine shows no abrupt deterioration of performance occurring in this type of machine until the Reynolds Number drops below 20,000. Apparently the wakes from the pre-rotation vanes play an important role in preventing severe laminar separation over the range of Reynolds Numbers covered.

LE DECROCHAGE TOURNANT DES MACHINES AXIALES GENERATRICES MONOETAGES; LOIS DE SIMILITUDE. Simon Goldstein and A. L. Jaumotte. ZAMP, May 25, 1957, pp. 235-251. 34 refs. In French. Study of the velocity of propagation of rotating stall to determine its effect on the frequency of the blade vibrations excited by this non-steady stall. The investigation is carried out on a single rotor. The similarity laws in the working region associated with rotating stall are found and the similarity laws relative to the velocity of propagation of stall are determined when a discontinuity in the characteristic curve is associated with this phenomenon. It is shown that the velocity of rotating stall may be determined from an induced phenomenon, either sound or vibration.

LOCAL COEFFICIENTS OF SKIN FRICTION AND HEAT TRANSFER FOR TURBULENT BOUNDARY LAYERS IN TWO-DIMENSIONAL DIFFUSERS. J. N. Hool. Gt. Brit., ARC R&M 2986, 1957. 12 pp. 10 refs. BIS, New York, $0.72. Study of the changes in local coefficients under rising pressure gradients. The values of the local coefficients of skin friction and heat transfer are compared on the basis of Reynolds' analogy, von Karman's improvement to Reynolds' analogy, and on the basis of similar velocity and temperature boundary-layer profiles. Tests on diffusers at total angles of 4° and 7° show that the local coefficients of heat transfer, based on the measured heat-transfer values, increase with increase of the stream velocity and diffuser angle relative to the local coefficients of heat transfer.

INVESTIGATION OF A SHORT-ANNULAR-DIFFUSER CONFIGURATION UTILIZING SUCTION AS A MEANS OF BOUNDARY-LAYER CONTROL. Stafford W. Wilbur and James T. Higginbotham. U.S., NACA TN 3996, June, 1957. 33 pp. Test results on several diffuser configurations which show that significant improvement in performance is obtained when a suction flow rate as small as 1% is utilized. Increased rates of suction are responsible for some additional improvements depending on the configuration of suction openings. Rounding the entrance of the suction holes and increasing the area through which suction is applied effectively decreases the auxiliary flow losses and thereby produces higher values of diffuser effectiveness. The diffuser-exit velocity distributions are also improved by the increase in suction area and by an increase in the amount of suction.

ON AXIALLY SYMMETRIC FLOW THROUGH ANNULAR BODIES IN COMPRESSIBLE FLOW. M. Z. v. Krzywoblocki. Istanbul Tek. U., Bul., No. 1, 1957, pp. 60-83. 28 refs. Linearized method for solving the problem analogous to that of the open-nosed slender body, in the domain of a compressible flow. Includes an illustrative example.

K RASCHETY VICHODNOGO UCHASTKA EZHEKTORA. M. V. Polikovskii. Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Jan., 1957, pp. 61-69. In Russian. Presentation of a method for the calculation of the inlet section of an ejector. The effect of the configuration on the pressure and cavitational characteristics is taken into account and it is assumed that the two mixing fluids are incompressible and have equal specific weights. A close agreement is found between the theory and the experiment.

FURTHER INVESTIGATIONS OF THE LAMINAR-TURBULENT TRANSITION IN A FREE JET (ANNULAR NOZZLE). O. Wehrmann and H. Fabian. Hermann Föttinger-Inst. für Strömungstech., Berlin Tech. U. Rep. (AFOSR TR 57-31) [AD126494], Dec., 1956. 43 pp. 10 refs. Investigation of the law governing the shedding frequency of the ring vortices as a function of the Reynolds Number, and to find the influence of the nozzle boundary layer. By application of a special calibration method it is possible to measure the velocity destribution of the vortices numerically and to determine with rather good accuracy the value of a critical vortex Reynolds Number which describes the final stage of a vortex before its three-dimensional decay. Three types of nozzle are used, and all three show the frequency laws and the transition phenomena characteristics. Acoustic control of the transition phenomena is discussed.

O PERIODICHNOSTI STRUI, VYKHODIASHCHEI IZ SIMMETRICHNOGO SOPLA NA RASCHETNOM REZHIME. G. A. Dombrovskii. AN SSSR Dokl., Mar. 1, 1957, pp. 58-61. In Russian. Analysis of the periodicity of a supersonic jet issuing from a symmetrical nozzle under rated conditions in the absence of compressibility fluctuations.

Stability & Control

CRITICAL FLIGHT CONDITIONS AND LOADS RESULTING FROM INERTIA CROSS-COUPLING AND AERODYNAMIC STABILITY DEFICIENCIES. W. J. G. Pinsker. (NATO AGARD Struc. & Materials Panel, Copenhagen, Apr., 1957.) Gt. Brit., RAE TN Aero. 2502, Mar., 1957. 44 pp. Discussion of the effects of gyroscopic forces on an aircraft with large inertias during rolling maneuvers, and presentation of criteria for three resulting divergent flight conditions: yaw divergence, pitch divergence, and autorotational rolling. The critical loading cases in practical rolling maneuvers

are analyzed, methods for determining peak loads are outlined, aircraft responses in inadvertent pitch-up are analyzed, and data are given for the estimation of peak loads both for uncontrolled conditions and for pitch-up with pilot's counteraction.

CHARTS FOR ESTIMATING THE EFFECTS OF SHORT-PERIOD STABILITY CHARACTERISTICS ON AIRPLANE VERTICAL-ACCELERATION AND PITCH-ANGLE RESPONSE IN CONTINUOUS ATMOSPHERIC TURBULENCE. Appendix - ANALYSIS OF AIRPLANE RESPONSES AS AFFECTED BY VARIATIONS IN THE DIMENSIONLESS PARAMETERS. K. G. Pratt and F. V. Bennett. US, NACA TN 3992, June, 1957. 61 pp. 11 refs. Presentation of charts in terms of four dimensionless parameters for estimating the root-mean-square vertical-acceleration and pitch-angle responses. The trends of the responses with each of four parameters are discussed in terms of two significant combinations of the parameters involved. The charts are best suited for application to rigid unswept-wing airplanes of not more than 200-ft. wingspan, flying at low subsonic speeds.

Wings & Airfoils

THE CALCULATION OF THE PRESSURE DISTRIBUTION OVER THE SURFACE OF TWO-DIMENSIONAL AND SWEPT WINGS WITH SYMMETRICAL AEROFOIL SECTIONS. J. Weber. Gt. Brit., ARC R&M 2918, 1956. 63 pp. 19 refs. BIS, New York, $3.15. Complete derivation of Riegels and Wittich's theory, including detailed discussion of the approximations made and their effect on the accuracy of the results. Calculated pressure distributions are identical with the exact values for airfoils of elliptic cross section, and the numerical values for Joukowsky airfoils agree well with the exact solutions. The method, which is particularly suitable for practical applications in that only knowledge of the section ordinates is required, is extended to sheared wings of infinite span and to the center section of swept wings, by means of Küchemann and Weber's solutions for zero lift and for the thin wing with lift.

A SERIES OF AEROFOILS DESIGNED TO DEVELOP EXCEPTIONALLY LARGE LIFT COEFFICIENTS WHEN BOUNDARY LAYER CONTROL BY BLOWING IS EMPLOYED. D. G. Hurley and P. R. Skeat. Australia, ARL Rep. A.102, Mar., 1957. 33 pp. Includes detailed theoretical investigation of one of the airfoils which has a thickness/chord ratio of 0.62, a trailing-edge angle of 90°, and a design lift coefficient of 9.69. The design method, which is an extension of classical free stream-line theory, is described and the velocities at the surface of an airfoil when at an incidence other than the design value are determined.

SOME THICKNESS DISTRIBUTIONS FOR NARROW WINGS. W. T. Lord and Barbara Green. Gt. Brit., RAE TN Aero.2495, Feb., 1957. 29 pp. Outline of a method for designing thickness distributions for narrow wings - particularly those with straight, unswept trailing edges. The method uses inviscid flow theory to design for low zero-lift wave drag in such a way that possible effects of boundary layers are taken into account in accordance with the ideas of Küchemann and Weber. For clarity, only delta wings with diamond cross sections and sharp leading edges are considered in detail.

A TECHNIQUE FOR IMPROVING THE PREDICTIONS OF LINEARISED THEORY ON THE DRAG OF STRAIGHT-EDGED WINGS. D. G. Randall. Gt. Brit., RAE TN Aero.2474, Jan., 1957. 41 pp. Analysis to show that, if the linearized equation of supersonic flow is used to determine the flow over straight-edged wings and the linearized boundary condition is replaced by the full (nonlinear) boundary condition, the discontinuities displayed in the slope at the various Mach Numbers for which the edges are sonic, disappear and are replaced by plausible values. On this basis a simple method is derived which gives satisfactory agreement with experimental data.

THE WAVE DRAG OF NON-LIFTING COMBINATIONS OF THIN WINGS AND "NON-SLENDER" BODIES. Appendix - PROPERTIES OF AXIAL MULTIPLE DISTRIBUTIONS. L. M. Sheppard. Gt. Brit., RAE TN Aero.2496, Mar., 1957. 26 pp. 19 refs. Presentation of an alternative to the appropriate Lomax-Heaslet multipole method. The procedure described is based on the assumption, fundamental to the area rule and the transfer rule, that the effect of the wave drag of the interference velocity potential, due to the interaction between the exposed wing and the fuselage, is negligible. Treatment includes an investigation, based on existing theoretical and experimental data, of the validity of the fundamental assumption, and discussion of the application of the multipole method to fuselage design for low combination wave drag - with special reference to an elliptic wing-body combination.

LIFT, DRAG, AND PITCHING-MOMENT CHARACTERISTICS OF AGARD CALIBRATION MODELS A AND B AT MACH NUMBERS 3.98 AND 4.98. C. J. Schueler. USAF AEDC TN 57-9 [AD 123507], May, 1957. 29 pp. Wind-tunnel tests on Model A over a Reynolds Number range from 1.4×10^6 to 6.8×10^6, and on Model B over a range from 1.0×10^6 to 4.6×10^6, based on body length. Data for Model A indicate that the lift-curve slope at zero lift is greater at Mach Number 4.98, and that, at each Mach Number and zero lift, the drag coefficients vary as the Reynolds Number increases; the total and forebody drag decreases slightly in the low Reynolds Number range and then increases in the high range; and the base drag increases, leveling off at Mach Number 3.98 above Reynolds Number 3.5×10^6. For Model B, the forebody and base-drag coefficients at each Mach Number varies with Reynolds Number in a way predicted by the Crocco-Lees theory.

TYPES OF SEPARATION VORTEX ON SWEPT WINGS. Akira Mitsuyasu and Masanori Hayashi. J. Japan Soc. Aero. Eng., May, 1957, pp. 1-5. In Japanese. Investigation of the growth of vortex patterns on various swept wings by using tufting, oil-film, and smoking techniques. The location of the part-span vortex relative to that of the broken band of oil black on the wing surface is confirmed:

with an increase in incidence it tends to move inwards; with a greater increase in incidence, a secondary part-span vortex is found in an inner region. The existence of a trailing-edge separation vortex is confirmed at considerable incidence, but is found not to extend over the whole span.

THIN AIRFOIL THEORY BASED ON APPROXIMATE SOLUTION OF THE TRANSONIC FLOW EQUATION. J. R. Spreiter and A. Y. Alksne. US, NACA TN 3970, May, 1957. 82 pp. 51 refs. Derivation of a method for the approximate solution of the nonlinear equations of transonic small-disturbance theory. Although the solutions are nonlinear, the results are obtained in closed analytic form for a large and significant class of nonlifting airfoils. Application to two-dimensional flows with a free-stream Mach Number near 1 leads to general expressions for the determination of the pressure distribution on an airfoil of specified geometry, and gives the correct variation of pressure with Mach Number for the shape of an airfoil having a prescribed pressure distribution. For flows that are subsonic everywhere, the method yields a pressure-correction formula that is more accurate than the Prandtl-Glauert rule. For flows supersonic everywhere, the method yields the equivalent, in transonic approximation, of simple wave theory.

ON THE WAVE DRAG OF WING-BODY COMBINATION MOVING AT SUPERSONIC SPEEDS. Ryuma Kawamura and Keiichi Karashima. J. Japan Soc. Aero. Eng., Apr., 1957, pp. 1-7. Theoretical investigation using linearized small-perturbation theory to find the potential functions due to the body and to the wing, respectively, by source distributions on the body axis and the wing plane. The interference-potential is determined such that the boundary conditions are satisfied on the wing plane and on the symmetry plane. A general expression for the wave drag of zero-lift wing-body combinations is derived in terms of the thickness distribution of the wing and the sectional area distribution of the body. A numerical calculation is carried out for a cone cylinder with a low-aspect-ratio delta wing.

A NOTE ON THE WAVE DRAG OF THE WING OF A RECTANGULAR WING AND BODY COMBINATION. L. M. Sheppard. Gt. Brit., RAE TN Aero. 2494, Jan., 1957. 8 pp. Derivation of a simple relationship between the zero-lift wave drag on an exposed wing and the wave drag of the portion of the gross wing blanketed by the body. Both are evaluated by ignoring the interference of other parts of the combination. The result is valid only when the tip Mach cones of the wing lie downstream from the blanketed wing. An example is presented for the case of wings with double-wedge section, the maximum thickness being midchord.

AEROELASTICITY

A METHOD OF CALCULATING THE SHORT-PERIOD LONGITUDINAL STABILITY DERIVATIVES OF A WING IN LINEARISED UNSTEADY COMPRESSIBLE FLOW. Appendix I, II - SMALL FREQUENCY OSCILLATIONS IN SUBSONIC FLOW. Appendix III - SUPERSONIC FLOW. Appendix IV - SOME MATHEMATICAL AIDS. K. W. Mangler. Gt. Brit., ARC R&M 2924, 1957. 36 pp. 38 refs. BIS, New York, $1.89. Analytical technique for finding the pressure distribution and the aerodynamic forces and moments on a wing performing harmonic pitching and heaving oscillations. The calculation, which is based on the assumption of inviscid potential flow without shock waves, applies to all Mach Numbers and is restricted to small incidence and to small values of reduced frequency. The method is easiest for M = 1 and results of a calculation for delta wings in this region indicate that the short-period oscillation near M = 1 will be unstable.

THE EFFECT OF AMPLITUDE ON THE TORSIONAL VIBRATIONS OF SOLID WINGS SUBJECTED TO AERODYNAMIC HEATING. Josef Singer. J. Aero. Sci., Aug., 1957, pp. 620-622. WADC-sponsored analysis using the Rayleigh-Ritz method in which the maximum potential energy is equated to the maximum kinetic energy for harmonic vibrations, yielding an expression for the angular frequency in terms of amplitude. An explicit expression is obtained for the relative frequency for any given temperature distribution and initial amplitude of vibration. A typical example is worked out to indicate the significance of the alleviating effect of the initial amplitude.

EXPERIMENTAL INFLUENCE COEFFICIENTS AND VIBRATION MODES OF A BUILT-UP 45° DELTA-WING SPECIMEN. Appendix - LEAST-SQUARE CORRECTION FOR ROLL. E. E. Kordes, E. T. Kruszewski, and D. J. Weidman. US, NACA TN 3999, May, 1957. 41 pp. Presentation of symmetrical and antisymmetrical static influence coefficients obtained on a three-point support, and of the first ten vibration modes and frequencies determined for an essentially free-free condition. Includes a detailed description of the structural properties of the specimen.

CALCUL DES FORMES ET FREQUENCES PROPRES D'UNE AILE DELTA MONTEE SUR UN AVION LIBRE DANS L'ESPACE A PARTIR DE COEFFICIENTS D'INFLUENCE MESURES AU MUR D'ESSAI. R. Kappus and D. Clerc. La Recherche Aéronautique, Mar.-Apr., 1957, pp. 37-40. In French. Calculation of shapes and natural frequencies of a delta wing mounted on an aircraft free in space in terms of influence coefficients measured on the test wall. The application of the systematization method is illustrated and it is shown that in the case of a not too rigid fuselage this flexibility should be taken into account by introducing supplementary data in order to avoid considerable deviation.

ON PANEL FLUTTER. Y. C. Fung. IAS Natl. Summer Meeting, Los Angeles, June 17--20, 1957, Preprint 749. 33 pp. 32 refs. Members, $0.75; nonmembers, $1.20. Theoretical and experimental investigation of large-amplitude flutter on a buckled plate two-dimensional flow. It is shown that an increase in the initial deviation from flatness raises the critical value of the reduced velocity. The static pressure differential across the plate has

very little effect on the critical reduced velocity if the differential is small, but becomes very effective in preventing flutter when the pressure differential is sufficiently large. Experiments show that the panel flutter in transonic and low-supersonic flow is essentially one of a single degree of freedom. For a plate of given thickness in a flow of given stagnation pressure, flutter first occurs at a critical Mach Number, and then may disappear at a higher Mach Number; the region of Mach Number in which flutter occurs decreases with increasing plate thickness. Galerkin's method is found applicable by comparing it to a solution using the Laplace transform method, as outlined by Goland and Luke.

FLUTTER OF CURVED PLATES WITH EDGE COMPRESSION IN SUPERSONIC FLOW. Y. C. Fung. (Midwest Conf. Fluid & Solid Mech., Ann Arbor, Apr. 1, 2, 1957.) GALCIT Rep. 5 (AFOSR TN 57-187), Apr., 1957. 32 pp. 12 refs. Calculation of the effects of initial curvature and of a static pressure differential across the plate in order to explain a significant discrepancy between previous theory and experiments on the large-amplitude flutter of buckled plates in a supersonic flow. Results, which are applicable to plates of infinite aspect ratio and to the simulated wind-tunnel experimental conditions, indicate that the critical flutter of a buckled plate is sensitive to the mean compressive load (the so-called "membrane" stress) in the plate, and that the static pressure differential across the plate, p, has very little effect on the critical reduced velocity when p is small, but becomes very effective in preventing flutter when p is sufficiently large.

FLIGHT TEST OF AN AUTOPILOT INSTALLATION AS A LATERAL GUST ALLEVIATOR IN A PT-26 AIRPLANE. Appendix A - LATERAL STABILITY CHARACTERISTICS OF PT-26 AIRPLANE WITH AND WITHOUT ALLEVIATOR INSTALLATION. Appendix B - DISCUSSION OF ATMOSPHERIC TURBULENCE EXISTING DURING DATA FLIGHTS. Charles Chalk. USAF WADC TR 55-269 (OTS, PB 121244), Mar., 1956. 63 pp. 11 refs. Investigation of the feasibility of alleviating lateral gust effects by using an autopilot plus rate gyros to sense angular rates. A special signal-mixer circuit is also tested. The system is shown to eliminate airplane lateral motions resulting from gusts. The signal mixer permits wide variation in magnitude and types of signals to the servos.

INVESTIGATION AT TRANSONIC SPEEDS OF DEFLECTORS AND SPOILERS AS GUST ALLEVIATORS ON A 35° SWEPT WING; TRANSONIC-BUMP METHOD. Delwin R. Croom and Jarrett K. Huffman. U.S., NACA TN 4006, June, 1957. 19 pp. Wind-tunnel tests over a Mach Number range from 0.40 to 1.15 and an angle of-attack range from -8° up to, and beyond, stall. Gust alleviation capabilities (as indicated by the reduction in lift-curve slope) are almost constant (approximately a 20% reduction in lift-curve slope) throughout the Mach Number range considered for both the deflector and the spoiler-deflector combination. Increased drag results from the deflection of these controls and indicates that they will also be effective as aerodynamic brakes during slow down to rough-air speed.

AIRPLANE DESIGN

EQUIPMENT COOLING SYSTEMS FOR AIRCRAFT. II - AIRCRAFT PENALTY METHODS AND SYSTEM COMPONENTS CHARACTERISTICS. R. H. Zimmerman. USAF WADC TR 54-359, Pt. 2, Sept., 1954 (May, 1956). 108 pp. 32 refs. Methods of evaluating aircraft performance losses from the operation of a cooling system, in terms of equivalent drag, increase in gross weight, reduced range, or reduced payload. Simulation methods for analyzing equipment items by means of an equipment component are developed. The physical characteristics and performance of coolant distribution systems are analyzed for constant-velocity, constant-pressure-gradient, and constant-diameter designs. An analytical representation of cooling load distribution along the header of a distribution system is developed and various heat exchangers applicable as intermediate components in cooling systems are analyzed.

Control Systems

ANALYSIS OF AN ELECTRICAL FLIGHT-CONTROL SYSTEM FOR INTERCEPTOR-TYPE AIRCRAFT. E. Price and R. Westerwick. (IAS Natl. Summer Meeting, Los Angeles, June 17--20, 1957, Preprint 744.) Aero. Eng. Rev., Aug., 1957, pp. 63-67. Discussion of a developmental program which centers around a closed-loop system using an airplane rate feedback. A cockpit test stand is built with one rotational degree of freedom to simulate pitching motion. Two types of stick configurations are evaluated - one that provides control to the airplane by electric signals only, and one that utilizes the mechanical control stick and obtains electrical control signals by suitable force transducers on the stick. Reliability studies lead to improvements made by paralleling circuits with a monitor for each circuit, and by underrating the components (powerwise). Two reliable circuits are described and compared.

Landing Gear

SOME CONSIDERATIONS OF HYSTERESIS EFFECTS ON TIRE MOTION AND WHEEL SHIMMY. Appendix A - EQUATIONS OF MOTION AND STABILITY CONDITIONS FOR A SIMPLE CASE OF WHEEL SHIMMY. Appendix B - DETERMINATION OF HYSTERESIS CONSTANTS FROM FREE-VIBRATION TESTS. Appendix C - CONSTANTS FOR CALCULATIONS. R. F. Smiley. US, NACA TN 4001, June, 1957. 45 pp. 10 refs. Theoretical investigation to provide an improved representation of tire hysteresis forces and moments for use in the analysis of tire-motion problems - particularly for wheel shimmy - and to illustrate the importance of hysteresis effects for a simple case of wheel shimmy. Smiley's linearized theory for tire motion and wheel shimmy is extended to account for the effects of rolling velocity and interaction between tire lateral distortion and twist on the hyster-

esis forces and moments. The concepts on which the analysis is based are outlined and the hysteresis equations developed are applied to two cases: the general shimmying motion of an untilted wheel for conditions where the wavelength of any lateral or torsional oscillation is large in comparison with the tire dimensions, and wheel shimmy where the wheel has only one degree of freedom - rotation about an inclined swivel.

ELECTRONICS

Amplifiers

DESIGN METHODS FOR MAGNETIC AMPLIFIERS AND SATURABLE REACTORS. James R. Walker and Max Frank. USAF WADC TR 56-281 [AD 110431], July 31, 1956. 592 pp. 30 refs. Discussion of full wave circuits of the center-tap, doubler, and bridge connections, in addition to some of the more recent half-wave circuits. The theory of operation for each of the various circuits is considered, describing the function of the core and rectifier components and the effects of their properties on amplifier response. The problems of stability resulting from a variance of environmental factors, amplifiers in cascade, and various types of loads together with some of the techniques of compensation are also studied. Designs with core configurations of toroids, U laminations, and C cores are described. Magnetic cores, rectifiers, wires, insulations, and encapsulation and potting materials are treated.

Magnetic Devices

FERROELECTRIC DEVICES. Appendix I - RAW MATERIALS EMPLOYED IN PREPARING DIELECTRIC MATERIALS. Appendix II - SECOND HARMONIC DIELECTRIC AMPLIFIER THEORETICAL ANALYSIS. Eugene Wainer. USAF WADC TR 56-362 [AD 97124], Dec., 1956. 130 pp. Investigation to evolve miniature devices for use in military aircraft especially under conditions of broad temperature ranges, i.e., from 65° to 250° C.; and to develop new and improved ferromagnetic materials for this purpose. Three practical devices are designed, constructed, and evaluated, and indications of the nature of the design are inferred for at least three other novel and useful compact ferroelectric units. Extensive measurements are presented for samples of a cadmium niobate/ sodium-niobate combination, the ferroelectric material which most nearly exhibits the desired characteristics, particularly nonlinearity over an extended temperature range. Results indicate that the principal effect of impurities is modification of the dielectric constant, and that the nonlinearity is some linear function of the dielectric constant.

FLIGHT OPERATING PROBLEMS

SIMULATION STUDY OF CONTROL OF AN AIRCRAFT AT OR NEAR THE ABSOLUTE CEILING. A. C. Robinson, J. W. Early, and B. J. Doody. USAF WADC TR 56-39 (OTS PB 121459), Mar., 1956. 46 pp. Development of dynamic equations of motion for the airframe, and evaluation of the dynamic and static characteristics of four types of controls for maintaining an aircraft at absolute ceiling. The control types studied include altitude, pitch angle, angle of attack, and airspeed. It is concluded that airspeed control is the best method.

FUELS & LUBRICANTS

PRELIMINARY PHOTOELASTIC DESIGN DATA FOR STRESSES IN ROCKET GRAINS. D. D. Ordahl and M. L. Williams. (ARS 11th Annual Meeting, New York, Nov. 26--29, 1956.) Jet Propulsion, June, 1957, pp. 657-662. Experimental investigation to find the quantitative relationships between the various parameters of grain geometry and the elastic stress distribution in the propellant, in order to establish a systematic approach to the problem of designing an internal-burning, star-perforated, propellant grain configuration that maintains the stress-concentration factor at a minimum practical value to achieve the maximum resistance to the various mechanical and thermal stresses the grain may undergo during the rocket's normal service life. Engineering design charts are presented showing the maximum stress developed as a function of the number of slots, the width of the slot, the wall thickness, and the shape of the star point. These charts can be used to determine the maximum stress developed in any prescribed configuration within the family investigated, provided the propellant properties are in the elastic range.

ICE FORMATION & PREVENTION

ICE CRYSTALS - A NEW ICING HAZARD. O. R. Ballard and B. Quan. CAI Annual Gen. Meeting, Ottawa, May 27, 28, 1957, Preprint 7/11. 12 pp. Members, $0.50; nonmembers, $1.00. Discussion of the nature of ice-crystal clouds and of crystal ice formation on anti-icing systems designed for supercooled droplet icing. Various methods of simulating icing conditions are reviewed and those used at the NRC for full gas-turbine tests are described. Study points out the importance of ice-detection systems which distinguish between supercooled and ice-crystal clouds.

SOME ASPECTS OF HELICOPTER ICING. J. R. Stallabrass. CAI Annual Gen. Meeting, Ottawa, May 27, 28, 1957, Preprint 7/9. 18 pp. Members, $0.50; nonmembers, $1.00. Discussion of the requirements for an icing-protection system and of the NRC's approach to the problem; description of the special spray rig constructed for the in-flight study of the phenomenon and for the testing of protective systems; consideration of rotor-blade icing effects on helicopter performance and handling, and of design problems associated with items other than primary lifting surfaces; and review of protection methods with particular emphasis on electrical methods.

MATERIALS

A REVIEW OF THE AIR FORCE MATERIALS RESEARCH AND DEVELOPMENT PROGRAM. Helen E. Hines and Ruth F. Walden. USAF WADC TR 53-373, Suppl. 3 [AD 110468], Oct., 1956. 90 pp. Summary of 145 technical reports and notes written during the period July 1, 1955 to June 30, 1956 and covering research into adhesives, metallurgy, analysis and measurement, biochemistry, textiles,

petroleum products, plastics, packaging, protective treatments and rubber. Includes contractor, investigator, and numerical indexes of all the technical reports issued during the period March, 1923 to June, 1956.

Metals & Alloys

STRUCTURAL MATERIALS FOR MISSILE APPLICATIONS AT VERY HIGH TEMPERATURES. J. R. Kattus. (ARS 11th Annual Meeting, New York, Nov. 26--29, 1956.) Jet Propulsion, June, 1957, pp. 644-649. Experimental determination of the short-time tensile, creep, and fracture properties of copper, iron, molybdenum, tantalum, and graphite at temperatures up to the melting points of the metals and up to 5,200°F. for the graphite. Results indicate that, for periods of time up to five minutes, the load-carrying abilities of tantalum and molybdenum exceed those of iron and copper at equal temperatures; that, although tantalum and molybdenum have appreciable strength in the temperature range 4,000° to 5,000°F., their service lives are limited because they are rapidly oxidized at these temperatures; and that graphite has relatively low strength at room temperature but it retains this strength with increasing temperatures up to 4,400°F. and higher, and is oxidized at a much slower rate than tantalum and molybdenum.

THE SELECTION OF STRUCTURAL MATERIALS FOR SUPERSONIC FLIGHT. D. D. Cox. IAS Natl. Summer Meeting, Los Angeles, June 17--20, 1957, Preprint 731. 14 pp. Members, $0.50; nonmembers, $0.85. Discussion of structural efficiency considerations for materials in an aircraft designed to fly in a given thermal environment. Comparison is made of various steel and titanium alloys, and it is shown that the load in the aircraft structure may, as the Mach Number increases, either increase, decrease, or remain constant, depending on the specific configuration and environment. It is also shown that the load-temperature relationship may be just as important as the strength/weight-temperature relationship in the determination of the structural material. Based on the material properties and the load variations as presented, titanium alloys show a considerable weight advantage over steel alloys for a broad range of temperatures and designs.

Metals & Alloys, Nonferrous

STUDIES OF FACTORS AFFECTING THERMAL STABILITY OF TITANIUM-BASE ALLOYS. F. C. Holden, H. R. Ogden, and R. I. Jaffee. USAF WADC TR 56-597 [AD 110748], Feb., 1957. 56 pp. Investigation to determine how thermal stability is affected by heat treatment, alloy composition and the introduction of strain. Thermal stability for MST-6Al-4V, Ti-155A, and C-130AM is good for heat-treatment conditions under creep exposure tests through 800°F. Some loss of ductility is observed in Ti-155A and C-130AM alloys fabricated in the beta field and annealed in the alpha-beta field. Substitutions of various beta stabilizers in a Ti-5Cr-5Mo alloy are made. Active eutectoid formers - nickel, copper, and chromium - are shown to be detrimental; thermal stability is improved by substitutions of manganese or molybdenum and by aluminum additions. Small amounts of strain have no significant effect.

MATHEMATICS

METRISABLE LIE GROUPS AND ALGEBRAS. S-T. Tsou and A. G. Walker. Proc. Royal Soc. (Edinburgh), Sect. A, 1955-57, pp. 290-304. Discussion of invariant tensor fields on a Lie group manifold. It is shown that their determination reduces to a purely algebraic problem connected with associated Lie algebra. A metrizable Lie algebra is defined, a number of decomposition and existence theorems are given, and it is shown that every metrizable algebra is the product of an abelian algebra and a number of nondecomposable reduced algebras. Examination of the number of independent metrics admitted by a metrizable algebra reveals that the metric is unique only when the complex extension of the algebra is simple.

ON A GENERALIZED DIRICHLET PROBLEM FOR PLURISUBHARMONIC FUNCTIONS AND PSEUDO-CONVEX DOMAINS; CHARACTERIZATION OF SILOV BOUNDARIES. H. J. Bremermann. Inst. Advanced Study, Princeton, N. J., Rep. (AFOSR TN 57-178) [AD 126473], Apr., 1957. 49 pp. 25 refs. Extension, from one to several complex variables, of the Perron-Caratheodory method for finding a harmonic function assuming given values on the boundary of a domain. A plurisubharmonic solution is derived which is closely connected with the envelope of holomorphy of a certain domain, can be computed explicitly, and, together with the corresponding plurisuperharmonic solution, provides an estimate for the variation of the harmonic solution (of 2n real variables) and solutions of similar differential operators under holomorphic transformations.

IMPROVED APPROXIMATIONS TO DIFFERENTIAL EQUATIONS BY DIFFERENCE EQUATIONS. W. R. Mann, C. L. Bradshaw, and J. G. Cox. J. Math. & Phys., Jan., 1957, pp. 408-415. OSR-supported method for reducing truncation error in a difference equation without introducing differences of higher order, in any one index, than the order of the differential equation.

A NEW PROOF OF THEOREMS OF PERRON AND FROBENIUS ON NON-NEGATIVE MATRICES. Alfred Brauer. N. C. U., TR 4 (AFOSR TN 56-576) [AD 110398], May, 1957. 17 pp. 15 refs. Analysis of a theorem which states that a positive matrix has a positive characteristic root ω which is greater than the absolute value of the other roots. The proof also gives a single method to compute ω, and a characteristic vector belonging to ω, as exactly as required, without determining the characteristic equation.

EIN VERFAHREN ZUR BILDUNG VON MATRIZANTEN. O. Hellman. ZAMM, Mar.-Apr., 1957, pp. 139-144. In German. Solutions of differential equations of the first order written in matrix form by means of the so-called matrizant. By this method the matrix A of the coefficients of

the given system of equations is partitioned into submatrices in such a way that the submatrices on the diagonal are square matrices; the matrixant for A is found by using the perturbation theory. Application is made to the problem of coupled flexural and torsional oscillations.

MISSILES

UNIVERSAL GRAVITY TURN TRAJECTORIES. Glen J. Culler and Burton D. Fried. J. Appl. Phys., June, 1957, pp. 672-676. Development of a method for integrating the differential equations of motion for gravity-turn trajectories, in the case of zero initial velocity. The method obviates the need for carrying out anew, for each missile preliminary design, computations involving nonlinear equations which require numerical integration. When expressed in terms of appropriate dimensionless variables, the resulting solutions are universal in the sense that they constitute a good approximation to any gravity turn with a small, nearly vertical, initial velocity. The solutions depend upon two parameters - the initial-thrust weight ratio and a parameter K which corresponds to the initial "kick angle" of nonsingular gravity turns.

NAVIGATION

PRINCIPLES OF SELF-CONTAINED NAVIGATION. H. H. Bailey. (IAS Natl. Summer Meeting, Los Angeles, June 17--20, 1957, Preprint 736.) Aero. Eng. Rev., Aug., 1957, pp. 68-73. Discussion of methods for providing all the necessary navigational equipment aboard the aircraft itself so that, in an emergency, it will be completely independent of ground aid. Study covers the basic principles of navigation, fixing methods, dead-reckoning techniques, and inertial navigation. The basic differential equation of all inertial systems is developed.

PHYSICS

BOUNDARY VALUE PROBLEMS IN KINETIC THEORY OF GASES. E. P. Gross, E. A. Jackson, and S. Ziering. Annals Phys., May, 1957, pp. 141-167. 17 refs. OSR-supported analysis from the viewpoint of kinetic theory, of the state of a gas flowing between two parallel plates. Consideration is given to the problem of finding a theory valid for arbitrary ratios of mean free path to plate distance and of plate speed to sound speed. A method of solution, which is applicable to the Boltzmann equation, is developed for the Bhatnager-Gross-Krook kinetic model. Variational principles are stated by noting the similarity of the linearized version of this theory to the Milne equation of radiative transfer; a new approach in the low-pressure region is indicated for the nonlinear, high-speed case; and the relationship to alternative methods is discussed.

POWER PLANTS

Jet & Turbine

SOME ASPECTS OF COMPRESSOR STAGE DESIGN. J. F. Louis and J. H. Horlock. Gt. Brit., ARC CP 319, 1957. 18 pp. BIS, New York, $0.54. Presentation of two approaches to the problem of modifying the design and improving the performance of a low-hub-tip ratio compressor stage at low flow rates. The direct problem of the performance of given compressor stages is considered first and results indicate how the blade sections of various designs approach the stall point. Next, a method is presented which combines the solutions of the indirect and direct problems and which enables a designer to determine stages satisfying the proposed design conditions and to predict their off-design performance up to the stalling point. The choice of reaction between stages differing in rotor and stator pressure-rise distribution is investigated in the off-design performance. Actuator-disc theory is used throughout to derive the equations of the flow.

AN INVESTIGATION OF THE HIGH ALTERNATING STRESSES IN THE BLADES OF AN AXIAL-FLOW COMPRESSOR. J. R. Forshaw. Gt. Brit., ARC R&M 2988, 1957. 19 pp. BIS, New York, $1.08. Experimental study which indicates that there is excitation at all speeds of low orders showing dissimilar flow in different parts of the stage and this excitation increases in a critical manner at or near stalling incidence indicating a partial stall which is localized in parts of the stage. At greater incidence the flow deteriorates, the contrast between various parts of the stage is reduced, and the level of the alternating stress falls to a value slightly higher than that at incidences lower than the partial stall. This phenomenon occurs for critical operating conditions and is different from stalling flutter. Both phenomena could occur in the same compressor; the latter would be influenced by blade stiffness and could occur over wide ranges of operation provided the incidence and mass flow are greater than lower boundaries.

CONTROLLING THE SUPERSONIC TURBOJET. de Havilland Gazette, June, 1957, pp. 100-106. Analysis of operations in terms of component parts. The need for a single-lever control to adjust for flight conditions some nine different variables in the engine is discussed, and such an automatic control is proposed. This system is a closed-loop control which senses the error in some measurable variable, and then reacts to reduce the error to zero. Engine speed is a commonly selected variable. Afterburner control employs a straightforward schedule of fuel supply in proportion to the compressor delivering pressure.

A DESIGN MANUAL FOR REGENERATIVE HEAT EXCHANGERS OF THE ROTARY TYPE. Appendix A---INFLUENCE OF CURVATURE IN DRUM TYPE MATRICES. Appendix B---WORK AND THERMAL EFFICIENCY OF AN ACTUAL REGENERATIVE GAS TURBINE CYCLE. Harold H. Sogin and Kamal-Eldin Hassan. USAF WADC TR 55-13, June, 1956. 107 pp. 31 refs. Development of Hausen's regenerator theory in a form directly applicable to the rotary machine, and examination of deviations from some of the underlying assumptions. A numerical method for calculating the performance of unbalanced regenerators is included, but this calculation is not required in applying the theory. Pressure-drop and heat-trans-

fer data for flame-trap and wire-screen matrices are assembled, and the effect of regenerative performance on the thermodynamic cycle is discussed. Includes a sample calculation.

Rocket

RELIABILITY CONCEPTS IN ROCKET POWER CONTROLS DESIGN. H. L. Coplen, Jr. (ARS 11th Annual Meeting, New York, Nov. 26-29, 1956.) Jet Propulsion, June, 1957, pp. 637-640, 643. Discussion of the principal power-control problems in a liquid-propellant rocket. These problems include propellant ignition, regulation during the thrust increase to rated thrust, malfunction detection during the starting transient, thrust control (if required), and mixture ratio or propellant-utilization control. It is pointed out that the design of a rocket power control system must be considered an inseparable part of the general engine-system design to achieve optimum performance, and that maximum reliability can be achieved only by a control system having functional simplicity resulting from real compatibility of the major engine components and the use of all inherent self-controlling elements in the system. The elimination of service systems, whether electrical, hydraulic, or pneumatic, in favor of direct actuation and sequencing from basic engine parameters is recommended as an approach to basic reliability. Other approaches are also endorsed.

SOME CONSIDERATIONS OF FILM COOLING FOR ROCKET MOTORS. M. J. Zucrow and A. R. Graham. (ARS Fall Meeting, Buffalo, Sept. 24-26, 1956.) Jet Propulsion, June, 1957, pp. 650-656. 28 refs. ONR-sponsored theoretical and experimental investigation of a 500-lb.-thrust, 500-psia combustion pressure rocket motor using white fuming nitric acid and jet-engine fuel (JP-4) as the propellants. Test data indicate that increasing the film-cooled length of a cylindrical section requires more than a proportional increase in film-coolant flow rate. Graphs are presented for determining the actual film-coolant flow rate after calculating an ideal rate (proportional to the average film-cooled length) when the heat-transfer rate to the liquid film is known. Circumferential variations in the length of the liquid film are taken into account by means of the profile effectiveness which depends upon the design of the film-coolant injector and the main propellant injector. Includes description of a method for estimating the heat transfer to the coolant, and experimental data for the loss in specific impulse when water is used as the coolant.

A DIRECT MEASUREMENT TECHNIQUE OF DETERMINING ROCKET EXHAUST VELOCITIES. L. E. Bollinger and Rudolph Edse. USAF WADC TR 56-336 [AD 110500] (OTS PB 121871, $1.00), Nov., 1956 (1957). 42 pp. 11 refs. Method for measuring supersonic gas velocities in which the front of a luminous wave is detected by a set of optical probes employing photomultiplier tubes. Signals from these probes are used to trigger an electronic 10-mc., six-channel chronograph which indicates in discrete steps the time required for the luminous wave to pass between any of the seven optical probes. The system is tested by measuring known detonation velocities of gaseous mixtures in the neighborhood of 10,000 ft./sec.

ROTATING WING AIRCRAFT

LONGITUDINAL STABILITY AND CONTROL OF THE SINGLE-ROTOR HELICOPTER. Appendix I - CALCULATION OF PARAMETERS OF HELICOPTER DERIVATIVES. Appendix II - CALCULATION OF CONSTANTS IN RESPONSE EQUATIONS. Appendix III - MORE EXACT CALCULATION OF AUTO-ROTATION DERIVATIVES. A. R. S. Bramwell. Gt. Brit., RAE Rep. Naval 1, Jan., 1957. 88 pp. 19 refs. Presentation and reduction to nondimensional form of the relevant equations of motion. Static and maneuvering stabilities are introduced in a manner analogous to fixed-wing aircraft practice, and it is shown that the static stability of the helicopter is proportional to the coefficient E in the stability quartic, while the maneuvering qualities are represented by coefficient C. The NACA divergence requirement is expressed in terms of the short-period motion. The force and moment derivatives for a single-rotor helicopter (including tailplane, if required) are given as simple formulas or in chart form, and comparisons are made with wind-tunnel and flight-test data wherever possible.

SPACE TRAVEL

NEKOTORYE VOPROSY DINAMIKI POLETA K LUNE. V. A. Egorov. AN SSSR Dokl., Mar. 1, 1957, pp. 46-49. In Russian. Discussion of dynamics of the flight to the moon, including such problems as the necessary speed, trajectory shape, orbit around the moon, and landing on the moon.

ON THE POWERED FLIGHT TRAJECTORY OF AN EARTH SATELLITE. B. D. Fried. Jet Propulsion, June, 1957, pp. 641-643. Theoretical investigation of the problem of programing the trajectory. A point-mass missile moving in a uniform gravitational field, with aerodynamic forces neglected, is considered in order to obtain the optimum trajectory by making the tangent of the angle ψ between the thrust vector and the horizontal a linear function of time. Result is valid for arbitrary time dependence of thrust and mass, including the discontinuities corresponding to staging. It is shown, moreover, that a linear time dependence is again obtained for tan ψ by replacing orbit altitude with some other function of burnout altitude and velocity vector, and by looking for a stationary solution. Explicit expressions for velocity and altitude with this type of thrust-attitude program are given for the particular case of constant thrust and mass-flow rate.

STRUCTURES

Bars & Rods

BENDING STRENGTH OF TUBING IN THE PLASTIC RANGE. Clifford S. Ades. J. Aero. Sci., Aug., 1957, pp. 605-610. 13 refs. Presentation of a method for determining the total work of a bent

and deformed tube subjected to stresses in the plastic range. By using the principle of least work, it is shown that it is possible to determine the shape of the cross section of the tube as a function of its longitudinal curvature and also, after the shape is found, to determine the bending moment carried by the tube. With this bending moment available, bending modulus-of-rupture charts for round tubing are constructed which appear to agree well with experimental results.

Beams & Columns

ELASTO-PLASTIC BENDING OF A BEAM UNDER PLANE STRAIN CONDITIONS. Y. V. G. Acharya. J. Aero. Soc. India, Feb., 1957, pp. 8-13. Investigation of bending in a beam, having a rectangular transverse section, under the action of a pure couple. It is shown that the application of von Mises' hypothesis yields a higher resisting moment than would be obtained by using Tresca's assumptions. Numerical values of moment coefficients have been derived using both hypotheses and including the effects of two distinct yield limits, as well as Poisson's effect. A comparative coefficient μ, which gives the ratio of the moment coefficient obtained by using the two hypotheses, is also evaluated.

Cylinders & Shells

SECOND-ORDER TORSION AND BENDING OF ISOTROPIC ELASTIC CYLINDERS. W. S. Blackburn and A. E. Green. Proc. Royal Soc. (London), Ser. A, June 11, 1957, pp. 408-422. Reduction of the solution for the second-order torsion of a cylinder of compressible isotropic material to a single boundary-value problem involving two complex potential functions. Without solving this problem, a formula for the fractional elongation of the cylinder is obtained in agreement with that found previously by Rivlin. The problem of second-order bending of such a cylinder by couples over its plane ends is also reduced to the solution of a single boundary-value problem for two complex potential functions. A general formula is found for the change in length of the line of centroids and an application is made to right circular cylinders.

WYBOCZENIE KOPUŁ KULISTYCH W SWIETLE BADAŃ MODELOWYCH. Aleksander Lisowski. Rozprawy Inżynierskie (Warsaw), No. 1, 1957, pp. 97-116. In Polish, with summaries in English and Russian. Method for determining the buckling modes of a shell and the value of the critical load. On the basis of model tests, the buckling mode is assumed to be the same type as the deflection surface due to the action of a concentrated force. It is shown that short cylindrical shells buckle in the form of a series of waves characterized by the dimension L along the curvature of the shell. For medium and long shells, in which the length of the shell is equal to several times its span, the form of a half-wave is decisive. For spherical dome, it is assumed that the decisive buckling mode is that of local stability loss. The range of the wave is determined by the radius r_0 obtained from the diagram of deflection of a shell loaded with a concentrated force.

INFLUENCE COEFFICIENTS FOR CIRCULAR CYLINDRICAL SHELLS WITH LINEARLY VARYING WALL THICKNESS. M. B. Sledd. GIT Eng. Exper. Sta. Rep. 2 (AFOSR TN 57-196) [AD126491], Apr. 10, 1957. 22 pp. 12 refs. Analysis of a thin-walled, elastic, right circular cylinder loaded on one edge with a uniformly distributed shearing force H_2 and a bending moment M_2, and with the other edge free. For purposes of subsequent comparison, expressions are recorded for the influence coefficients of the shell with constant wall thickness and semi-infinite axial length, and for a shell with constant wall thickness and finite axis length. Consideration is then given to expressions for varying thickness, including the following: radial displacement, rotation, horizontal stress resultant, and bending moment - all as functions of axial distance. These expressions are used to obtain coefficients for a shell loaded along its thicker edge. The results are expressed in terms of Kelvin functions, and compared graphically with those previously recorded for shells of constant thickness.

AN ELASTIC CIRCULAR RING SUBJECTED TO AN ARBITRARY LOAD. F. Szelągowski. Bul. Acad. Polonaise Sci. (Warsaw), No. 2, 1957, pp. 67-75. Theoretical investigation to determine the stresses and displacements at any point of the ring. Relations are established between the value of the holomorphic function f (z) at any point of the annular region and the value of the real and imaginary part of that function on the outer circle of radius R and on the inner circle of radius ρ. The method developed is additionally applicable for solving similar problems concerning doubly connected regions which can be mapped conformally into a circular ring.

A DERIVATION OF THE EQUATIONS OF SHELL THEORY FOR GENERAL ORTHOGONAL COORDINATES. J. K. Knowles and Eric Reissner. J. Math. & Phys., Jan., 1957, pp. 351-358. ONR-supported analysis applying arbitrary orthogonal coordinates on the middle surface of a shell to avoid the use of oblique space coordinates and the notion of stress and strain referred to in such oblique coordinates.

Elasticity & Plasticity

DEFORMATION ENERGY AND THE STRESS-STRAIN RELATIONS FOR ISOTROPIC MATERIALS. T. Y. Thomas. J. Math. & Phys., Jan., 1957, pp. 335-350. Analysis to determine under what conditions the energy E of an isotropic medium will be a scalar invariant of a symmetric stress tensor σ the strain tensor ϵ, and the density ρ.

AN EXPERIMENTAL INVESTIGATION OF THE YIELD CRITERION AND THE STRESS-STRAIN LAW. G. Lianis and H. Ford. J. Mech. & Phys. Solids, No. 3, 1957, pp. 215-222. Application of notched strips loaded in tension under conditions of plane stress to verify the yield stress and stress-strain law in the plastic region. A new method to obtain ideally plastic material is employed. The experimental results compare favorably with the von Mises criterion and the Prandtl-Reuss flow rule.

MATERIALS-PROPERTY-DESIGN CRITERIA FOR METALS. IV - ELASTIC MODULI: THEIR DETERMINATION AND LIMITS OF APPLICATION. S. A. Gordon, R. Simon, and W. P. Achbach. USAF WADC TR 55-150, Pt. 4 [AD 110475], Oct., 1956. 18 pp. Study of the modulus of elasticity, for several materials at elevated temperatures, as it is derived from the conventional stress-strain curve and as it is derived from the determination of the velocity of propagation of elastic waves. The two methods give modulus values which agree closely in regions of low stress and where time effects are unimportant. At higher stress levels the dynamic modulus is higher than the statically determined modulus.

ON THE PROBLEM OF UNIQUENESS IN THE THEORY OF A RIGID-PLASTIC SOLID. III. R. Hill. J. Mech. & Phys. Solids, No. 3, 1957, pp. 153-161. Analysis of the boundary-value problem when there is no restriction on geometry changes within the solid. It is supposed that the change in the load vector on each infinitesimal element of the surface S_f is assigned irrespective of the change in its area, and by this method the rate of change of the nominal traction, based on the configuration at the initial instant, is given. A sufficient condition for uniqueness is then established under quite general loading conditions. A method is presented for determining in any given situation a critical rate of workhardening above which the mode is certainly unique and below which it probably is not.

ELASTIC WAVES IN ANISOTROPIC MEDIA. J. L. Synge. J. Math. & Phys., Jan., 1957, pp. 323-334. OSR-supported study of some known results set down in tensor notation, and development of some new general results for waves in a layer of anisotropic material. A generalization of Rayleigh waves exists at the limit at which the layer becomes a half-space, and it is found that, for a given frequency the surface waves either do not exist at all, or are propagated in certain discrete directions with certain speeds. Some calculations are made for a medium possessing transverse isotropy, and it is shown that the slowness surface (or, equivalently, the wave surface) possesses a spheroidal sheet.

LE CALCUL DES VARIATIONS EN ELASTICITE; APPLICATIONS - FLAMBAGE DES SURFACES. B. Dorléac. Docaéro, May, 1957, pp. 35-50. In French. Presentation of a method to calculate the variations of elasticity and evaluation of the method in terms of its advantages and limitations. The application entails a direct approach involving the calculation of large apertures and an indirect approach involving determination of buckling conditions for given thin surfaces. A generalization of the Euler equation is included in the calculation.

VERSCHIEBUNGSFUNKTIONEN FÜR ELASTISCHE SCHWINGUNGSPROBLEME. W. Noll. ZAMM, Mar.-Apr., 1957, pp. 81-87. In German. ONR-supported development in a generalized manner of the displacement potential of Gelerkin-Westergaard and Love's function in such a manner that they can be used not only for static problems, but also for vibration problems of linear elasticity. It is shown that Love's function exists exactly for those problems in which the curl of the displacement field is parallel to a fixed plane. In order to render the method more applicable, displacements and stresses are expressed in terms of Love's function for general cylindrical and spherical coordinates.

THE EFFECTS OF INELASTIC ACTION ON THE RESISTANCE TO VARIOUS TYPES OF LOADS OF DUCTILE MEMBERS MADE FROM VARIOUS CLASSES OF METALS. I - ECCENTRICALLY-LOADED TENSION MEMBERS HAVING ANGLE- AND T-SECTIONS, O. M. Sidebottom and M. E. Clark. II - INELASTIC BEHAVIOR OF ALUMINUM ALLOY I-BEAMS WITH RECTANGULAR WEB SECTION CUTOUTS, Will J. Worley and Shuji Taira. USAF WADC TR 56-330, Pts. I, II [AD 118178; 118-185], Apr., 1957. 99; 58 pp. 36 refs. Theoretical and experimental investigation to determine the load necessary to produce any given depth of yielding in angle- and T-sections subjected to eccentric tensile loading. The load is found analytically from the intersection of a constant depth-of-yielding interaction curve and a moment-load curve. Eccentric load tests are made on angle- and T-section members constructed from various classes of materials. The three materials used include SAE 4340 alloy steel, type 304 stainless steel, and 7075-T6 aluminum alloy. The angle-section members are tested with the principle axes oriented in three different positions with respect to the loading plane. It is found that deviations from the theory can be explained by variations in the stress-strain properties of the materials. Exploratory tests are made on an aluminum I-beam with cutouts. The mechanism analysis is used to predict the ultimate loads and the load deformation.

Plates

CERTAIN STABILITY PROBLEMS OF RECTANGULAR PLATES. Witold Nowacki and Marek Sokołowski. Arch. Mech. Stosowanej, No. 2, 1957, pp. 109-124. Analysis to determine the critical loads of rectangular plates simply supported on two opposite edges and having different boundary conditions along the two remaining edges. The method used involves the replacement of the differential equation of the problem by the equivalent integral equation which is, in turn, replaced by an infinite system of secular linear equations. (The buckling condition is the principal determinant of this system set equal to zero.) Then the critical load of the plate is directly obtained from the lowest eigenvalue of the kernel of the integral equation.

NOŚNOŚĆ GRANICZNA NIEJEDNORODNYCH WIRUJĄCYCH TARCZ KOŁOWYCH. Michał Życzkowski. Rozprawy Inżynierskie (Warsaw), No. 1, 1957, pp. 49-96. 29 refs. In Polish, with summaries in English and Russian. Analysis to determine the limit state of nonhomogeneous, varying-thickness, rotating disks using two different yield conditions - energy of distortion condition and maximum shear stress. The considerations are confined to the determination of the limit angular velocity and

the stress distribution. They retain their validity both in the Hencky-Iliushin theory of small elastic-plastic deformations, and in the Prandtl-Reuss and Levy-Mises theory of plastic flow.

Testing

THE EFFECT OF STRESS ON MICROHARDNESS. F. H. Vitovec. USAF WADC TR 56-282 [AD 97201], Aug., 1956. 22 pp. 20 refs. Investigation of microhardness as a function of test load for mild steel Armco iron, copper, brass, zinc, and cadmium. At light loads a discontinuity of slope in the hardness-load curve is observed which can be attributed to subgrain structure. A tension-compression fixture is developed and used to study the effect of stress on the microhardness of mild steel, brass, and copper specimens. For initially stress-free specimens, tensile stress causes a decrease in microhardness over a certain range of test load, and compressive stress results in a slight increase. The effect of stress on microhardness is complicated by the discontinous slope in the hardness-load curve introduced by subgrain structure effects.

Thermal Stress

A SIMPLE MODEL STUDY OF TRANSIENT TEMPERATURE AND THERMAL STRESS DISTRIBUTION DUE TO AERODYNAMIC HEATING. Gabriel Isakson. J. Aero. Sci., Aug., 1957, pp. 611-619. 13 refs. Abridged. Investigation of two cases: a) that of convective heat transfer into one side of a flat plate, representing a thick skin, and the effect of the resulting temperature distribution in inducing thermal stresses associated with bending restraint at the plate edges; b) that of the wide-flanged I-beam with convective heat transfer into the outer faces of the flanges. Numerical results are presented for the transient temperature differentials in the plate and in the beam when the environmental temperature first increases linearly with time and then remains constant, the period of linear increase representing the time of acceleration of the aircraft.

O RASPREDELENII TEMPERATURY V NEODNORODNOM STERZHNE PEREMENNOGO SECHENIIA, OBTEKAEMOM GAZOM. G. A. Tirskii. Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Jan., 1957, pp. 70-76. In Russian. Study of the stationary problem of temperature distribution in a rod with arbitrary heat-conductivity coefficients along its length, cross section, perameters, and the thermal flow past the rod. The obtained solution is to be applied to the calculation of the temperature curve on a gas-turbine blade with variable cross section in a gas flow with an arbitrary temperature distribution.

EFFECTS OF RAPID HEATING ON STRENGTH OF AIRFRAME COMPONENTS. R. A. Pride, J. B. Hall, Jr., and M. S. Anderson. US, NACA TN 4051, June, 1957. 14 pp. Experimental investigation to determine the influence of aerothermodynamic stresses on the bending strength of multiweb beams and ring-stiffened cylinders. Results indicate that thermal stresses reduce the bending load carried at buckling by both beams and cylinders. The influence of thermal stress on maximum load is found to depend largely on the mode of buckling. No effect is observed on the maximum load of beams that buckle locally, but a reduction in maximum load is noted for cylinders and for beams that buckle in the wrinkling mode. Includes some typical stress-shortening diagrams and associated buckling modes.

CREEP BEHAVIOR OF CIRCULAR PLATES. B. Venkatraman and P. G. Hodge, Jr. Polytech. Inst. Bklyn., Dept. Aero. Eng. & Appl. Mech., PIBAL Rep. 369 (AFOSR TN 57-135) [AD 120491], Mar., 1957. 27 pp. 13 refs. Analysis of creep deformations and stress distributions in circular plates subjected to normal pressure using a creep law based upon a flow rule associated with a maximum shearing stress. Steady-state conditions are assumed, and closed form solutions for moments and creep deformations are presented for simply supported and clamped edges.

THERMAL STRESSES AND THERMAL BUCKLING. Josef Singer, M. Anliker, and S. Lederman. USAF WADC TR 57-69 [AD 118287], Apr., 1957. 109 pp. 12 refs. Derivation, discussion, and generalization to include the variable-thickness case, of methods available for analyzing thermal stresses in flat plates having rectangular plan form and constant or variable thickness. Recommendations are made for practical calculation of the thermal stresses. Includes electromagnetic induction-heater experiments to verify the thermal buckling theory for the coverplates of multicellular supersonic-wing structures.

THERMAL CREEP DESIGN CRITERIA. Robert Goldin. IAS Natl. Summer Meeting, Los Angeles, June 17--20, 1957, Preprint 730. 11 pp. Members, $0.35; nonmembers, $0.75. Discussion of the effects of creep on yield strength, ultimate strength, fatigue strength, and rigidity. Elevation temperature criteria are presented for translating load-temperature-life conditions and material property into actual cross-sectional area of structural elements.

Wings

FATIGUE CHARACTERISTICS OF A RIVETED 24S-T ALUMINIUM ALLOY WING. II - STRESS ANALYSIS. M. R. Rice. Australia, ARL Rep. SM.247, Oct., 1956. 27 pp. 12 refs. Experimental investigation to determine the stress distribution in the critical areas of the P-51D Mustang mainplane. The theoretical stress concentration factors at the points of initial fatigue failure are estimated analytically, and in one case compared with the results from a brittle lacquer test. Strain measurements are made on six wings before and after preloading to investigate the resulting redistribution of stress. The measured and estimated strain distributions are presented graphically. The estimated stress concentration factors are tabulated with the corresponding local stresses.

THERMODYNAMICS

Combustion

FLAME ZONE STUDIES. IV - MICROSTRUCTURE AND MATERIAL TRANSPORT IN A LAMINAR PROPANE-AIR FLAME FRONT. R. M. Fristrom and A. A. Westenberg. Comb. & Flame, June, 1957, pp. 217-228. Navy-supported presentation of experimental data for a stoichiometric, 1/4 atm., propane-air flame. Data include a derived temperature profile and measurements, obtained by means of the particle-track technique, of velocity normal to the flame front and of stream-tube area parallel to the flame front. Also included is a set of sampled composition profiles for all stable species present. These profiles are obtained with a quartz microprobe and mass spectrometric analysis. The total flux due to both convection and diffusion is calculated for each species and the data are examined in terms of conservation of mass.

SOME LIMITING OXYGEN CONCENTRATIONS FOR DIFFUSION FLAMES IN AIR DILUTED WITH NITROGEN. R. F. Simmons and H. G. Wolfhard. Comb. & Flame, June, 1957, pp. 155--161. Experimental investigation to determine the nitrogen concentration required to extinguish the flame resulting from the burning of fuels at the surface of a porous, hemispherical, stainless-steel burner. Results are given for a number of fuels in terms of the limiting oxygen index, and it is found that the values are close to those obtained for premixed flames involving the fuel and oxygen in stoichiometric proportions. Calculations of the adiabatic flame temperature for stoichiometric mixtures with limiting oxygen index indicate that the limit is primarily determined by the flame temperature.

MIXING AND COMBUSTION IN FREE AND ENCLOSED TURBULENT JET DIFFUSION FLAMES. P. D. Sunavala, C. Hulse, and M. W. Thring. Comb. & Flame, June, 1957, pp. 179-193. 21 refs. Consideration of a number of theoretical aspects of both free and enclosed jets, and experimental investigation using both isothermal and hot jets, with respect to the surrounding air.

WIND TUNNELS & RESEARCH FACILITIES

A HIGH STAGNATION TEMPERATURE INTERMITTENT FLOW SUPERSONIC WIND TUNNEL. J. L. Harkness. Texas U., DRL No. 406 (AFOSR TN 57-222) [AD 126520], Mar. 11, 1957. 48 pp. Description of high-stagnation temperature, intermittent-flow, supersonic wind tunnel. Each basic component of the wind tunnel is given along with currently available instrumentation for model testing. The design and development work on the supersonic nozzles is covered in detail, and flow calibration data using the Mach 5 nozzle are presented. Mach Number distributions in the supersonic test region are included as well as stagnation temperature distributions in the stilling chamber and in the supersonic test region.

THE EFFECTS OF LIQUEFACTION OF AIR ON THE PRESSURE DISTRIBUTION AND FORCES ON A CONE CYLINDER BODY AT M = 5.0. W. T. Strike and W. N. MacDermott. USAF AEDC TN 57-14 [AD 123509], June, 1957. 44 pp. 11 refs. Determination of effects of liquefaction on the nozzle calibration as well as on the model pressure distribution and overall integrated forces. Although the experimental data is subject to other effects than just liquefaction, it is shown that the phenomenon of evaporation of liquid air droplets in crossing bow shock waves allows useful aerodynamic data to be obtained for a 100° F. range below the onset of liquefaction in the ambient flow.

FIXING BOUNDARY-LAYER TRANSITION ON SUPERSONIC WIND-TUNNEL MODELS. Marvin Luther. J. Aero Sci., Aug., 1957, pp. 579-586. Investigation to study the use of a single element and distributed roughness to fix transition, in order to reduce or eliminate scale effects on models. The character of roughnesses which would promote transition with minimum collateral effect on the flow is determined. Curves are presented showing critical roughness height as a function of Mach and Reynolds Numbers. Schlieren photographs are also presented to show the effect of Reynolds Number, roughness height, and angle of attack on the transition point. The models used for the study are a family of cone-ogive-cylinders with a fineness ratio of 10.6.

ON THE CHOICE OF THE WORKING FLUID FOR INTERMITTENT SUPERSONIC WIND TUNNELS. G. A. Bird and G. M. Lilley. Coll. of Aeronautics, Cranfield, Rep. 112, Jan., 1957. 21 pp. Discussion of the advantages and disadvantages of using a gas other than air in a wind tunnel. It is shown that in certain cases an intermittent tunnel may be more suitable than a continuous tunnel for use with these gases. A number of gases and gas mixtures (air, Freon 12, helium, and Freon 12-Argon) are compared on the basis of their Reynolds Number versus Mach Number characteristics when expanded from given stagnation conditions; the limitations which are imposed on the maximum Mach Number by the condensation are calculated.

THOUGHTS ON SUPERSONIC WIND TUNNELS WITH LOW FREE-STREAM DISTURBANCES. M. V. Morkovin. Johns Hopkins U., Dep. Aero. Rep. (AFOSR TN 56-540) [AD 110359], Nov., 1956. 20 pp. 23 refs. Discussion of disturbances in supersonic sections, classified as nonuniformity in the mean flow and unsteady disturbances, and principles for minimizing these disturbances. It is concluded that a large ratio of the settling chamber area to the area of the sonic throat decreases effectively those mean Mach Number nonuniformities which come from upstream of the throat. Care in keeping nozzle contours continuously curving without bumps or waviness minimizes not only the mean disturbance wave pattern, but also the unsteady, often dominating, sound level from "shivering Mach waves" Supersonic turbulence (vorticity fluctuations) is effectively suppressed by a large contraction ratio. Entropy (temperature) fluctuations can be reduced by matching mean temperatures at any duct junctures and by providing "long passage time" from such junctures to the test section.

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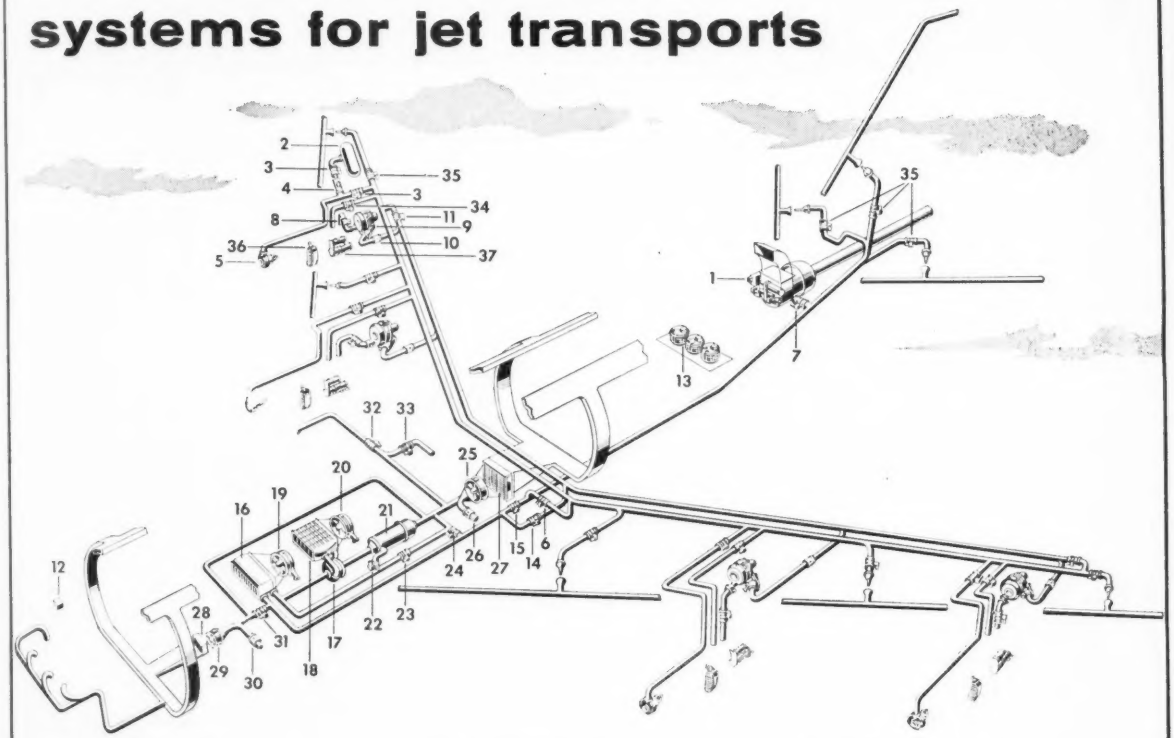

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20. Secondary Heat Exchanger Cooling Air Fan
21. Water Separator
22. Water Separator Anti-icing Control Valve
23. Turbine By-pass Valve
24. Cabin Hot By-pass Valve
25. Cabin Recirculating Fan
26. Cabin Recirculating Fan Check Valve
27. Cabin Electric Heater
28. Flight Station Electric Heater
29. Flight Station Recirculating Fan
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Electronic Crowbar Protects Transmitter. Roger G. Wenner. *Electronics*, June 1, 1957, pp. 174–176. Description of a circuit to protect power tubes from flash arc by instantly removing, in the event of a fault, the available energy by short circuiting the power supply with a device to dissipate the power.

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Where Do We Stand on Data Link. James Holahan. *Av. Age*, May, 1957, pp. 104, 105, 106–109 ff. Comparison of different types of data-link systems, and discussion of problems in selecting a multiplexing method and a radio carrier.

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An Age of Refinement for Special Purpose Tubes. Harry F. Dart. *Westinghouse Engr.*, May, 1957, pp. 74–78. Discussion of improvements in tube components that have resulted in increased power densities, improved performance characteristics, and a higher degree of reliability.

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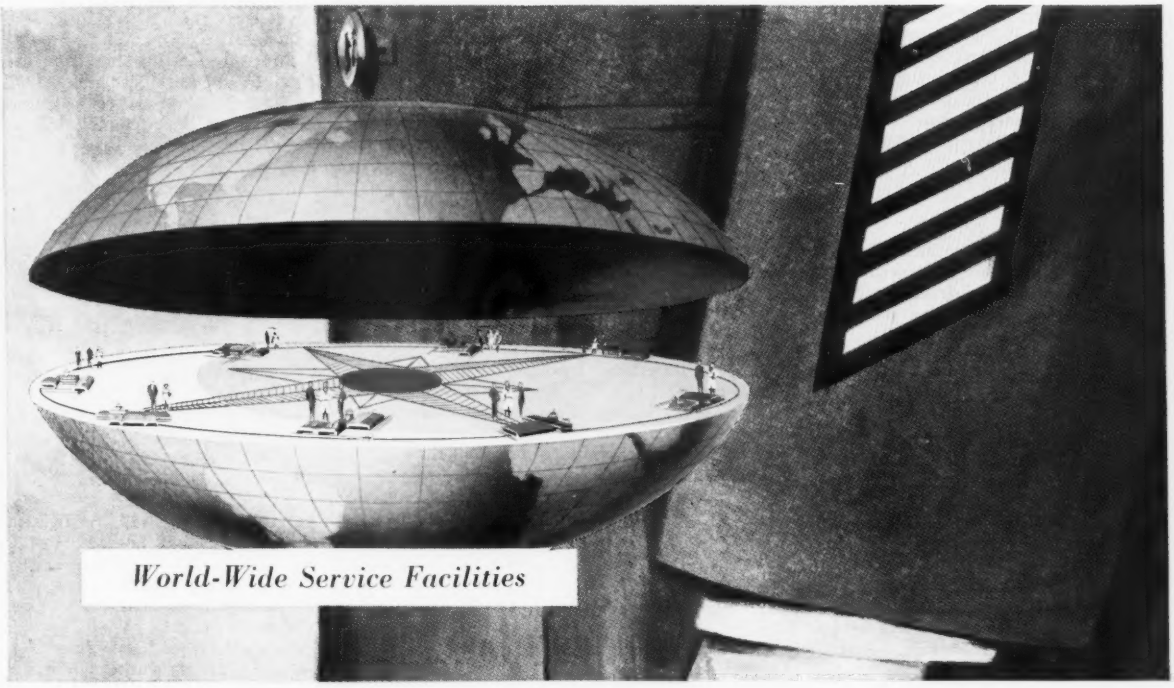
A VETERAN SERVICE ORGANIZATION



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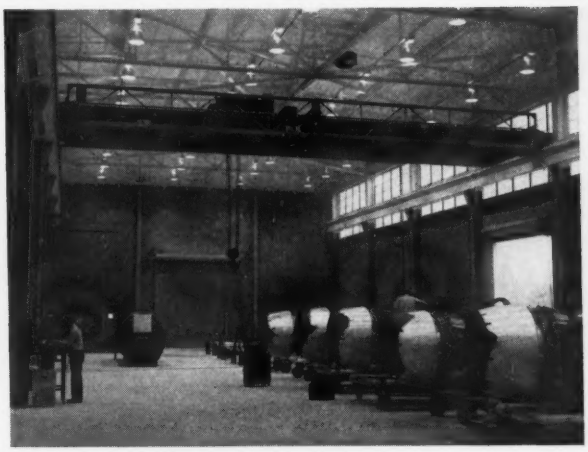

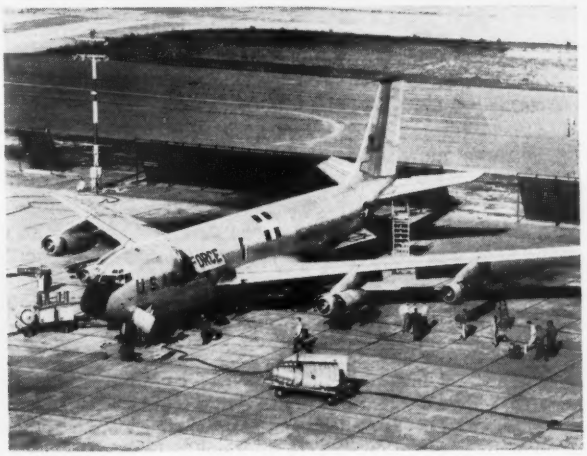

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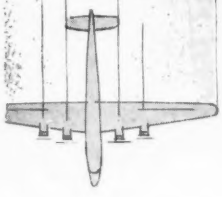

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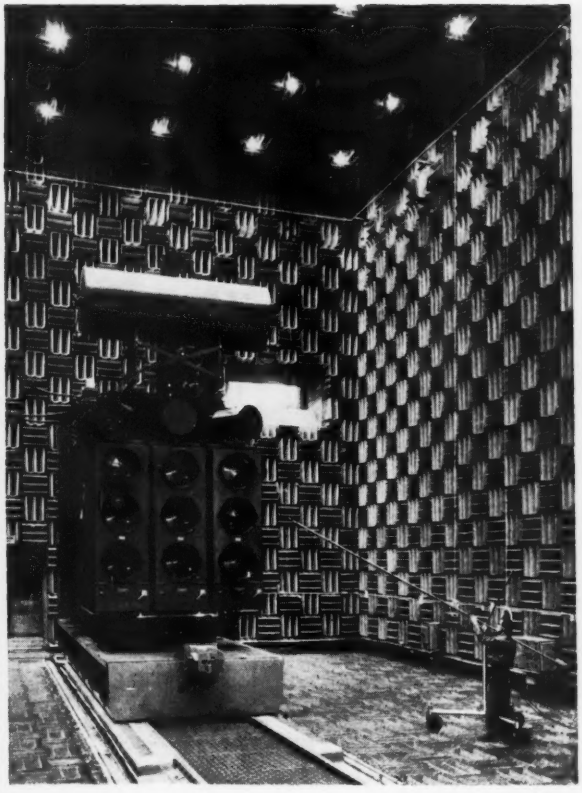

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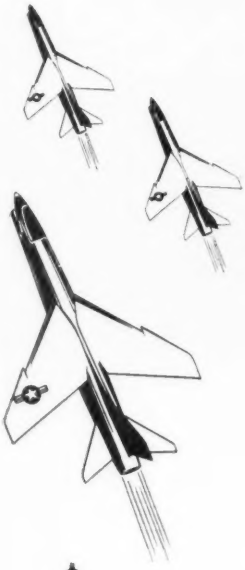

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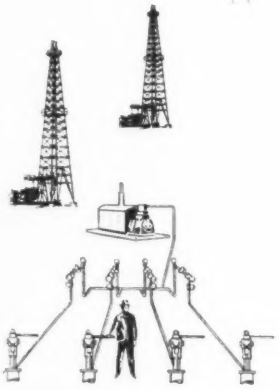

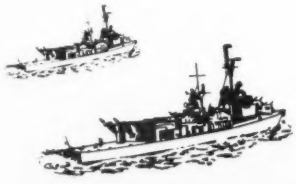

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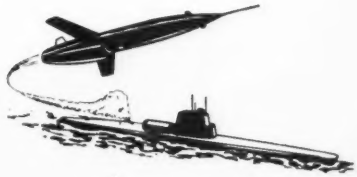

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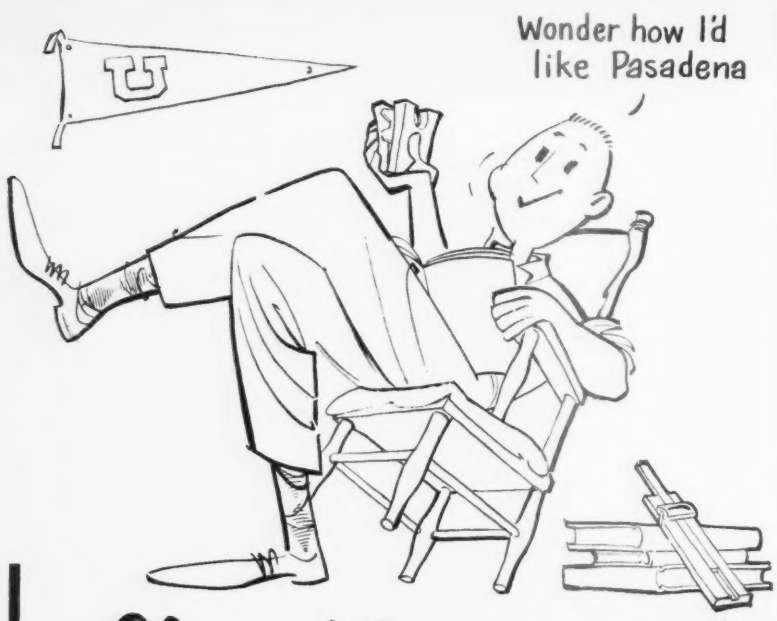

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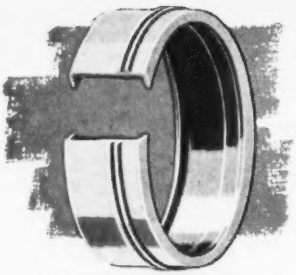

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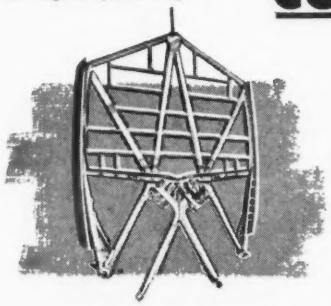

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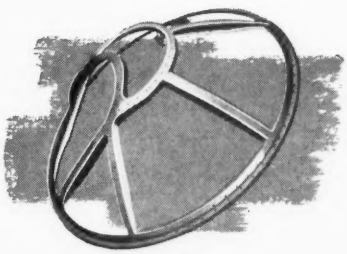

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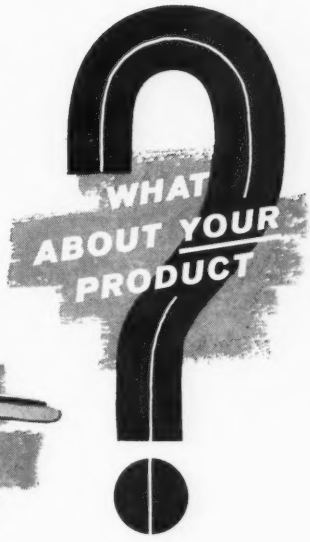

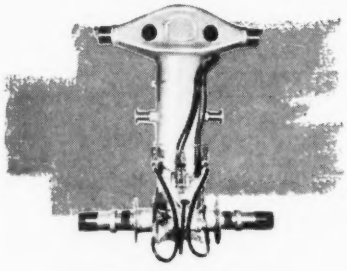

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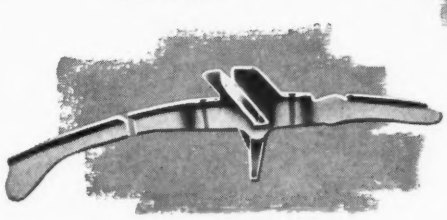

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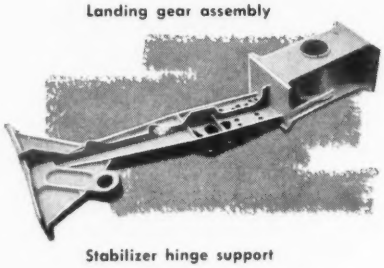

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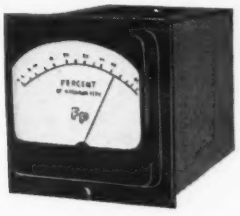

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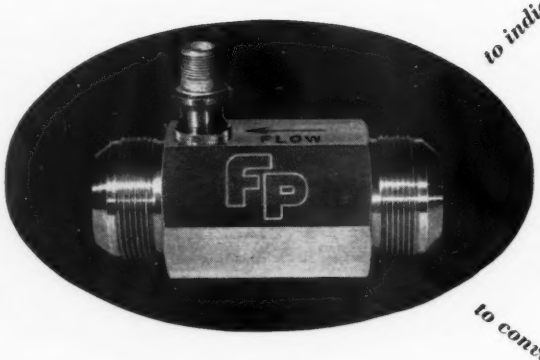

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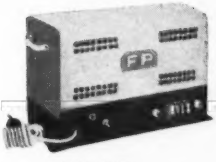

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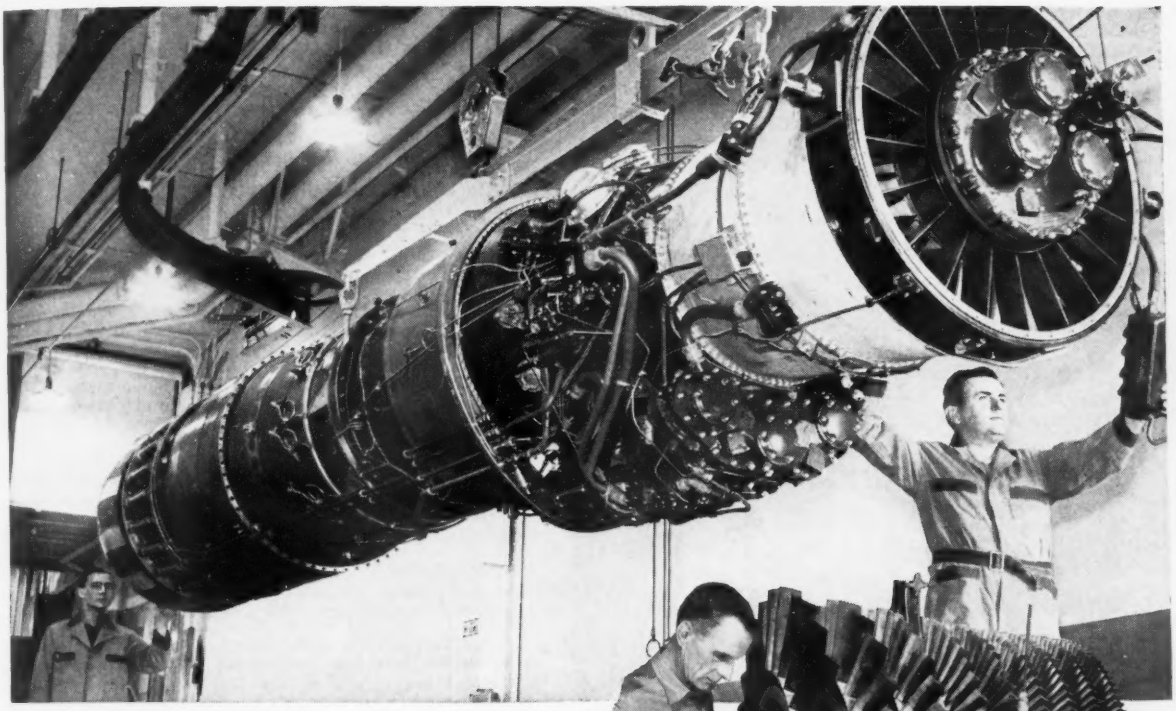

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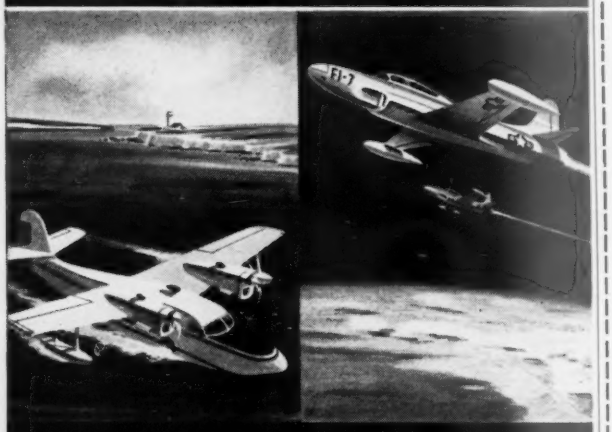

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Aeronautical Reviews — BOOKS

ACOUSTICS

Comparison of the Take-Off Noise Characteristics of the Caravelle Jet Airliner and of Conventional Propeller-Driven Airliners. Laymon N. Miller and Leo L. Beranek. (Presented at the Acoustical Society of America, 53rd Meeting, New York, May 25, 1957.) Prepared for The Port of New York Authority. Cambridge, Mass., Bolt Beranek and Newman, Inc., May, 1957. 44 pp., illus., diagrs., tables.

Based on noise measurements made at Orly Airport, Paris, and at New York International Airport, this report concludes that the noise characteristics of the Caravelle jet transport and those of four-engined propeller-driven transport planes now in commercial service differ in character but, to the hearer, the external sound is comparable. Both high and shallow climb techniques were employed during these measurements, which established that the comparative noise levels of the Caravelle, when considered in terms of subjective response to the spectrum distribution of the noise, were equal to or lower than those of large propeller aircraft and that the Caravelle noise persists for longer time intervals than propeller aircraft noise.

Acoustical Engineering. Harry F. Olson. Princeton, N.J., D. Van Nostrand Company, Inc., 1957. 718 pp., diagrs., tables. $13.50.

This book is based on an earlier work entitled *Elements of Acoustical Engineering*, published in 1940 and 1947, which originated from a series of lectures presented at Columbia University on the fundamental principles of modern acoustics. It now presents complete working methods, from fundamentals to practical applications, covering the entire field of acoustical engineering. Two chapters have been added dealing with complete sound-reproducing systems and communications systems. The author, who is Director, Acoustical and Electromechanical Research Laboratory, RCA Laboratories, has concentrated on the development of analogies between electrical, mechanical, and acoustical systems as a tool in the analysis of vibrating systems. The text is aided by the use of a large number of formulas, tables, and graphs.

Contents: (1) Sound Waves. (2) Acoustical Radiating Systems. (3) Mechanical Vibrating Systems. (4) Dynamical Analogies. (5) Acoustical Elements. (6) Direct Radiator Loudspeakers. (7) Horn Loudspeakers. (8) Microphones. (9) Miscellaneous Transducers. (10) Measurements. (11) Architectural Acoustics and the Collection and Dispersion of Sound. (12) Speech, Music and Hearing. (13) Complete Sound Reproducing Systems. (14) Means for the Communication of Information. (15) Underwater Sound. (16) Ultrasonics. Index.

AERODYNAMICS

Cours de Mécanique du Vol (A Course in the Mechanics of Flight). A. Turcat. Paris, Dunod, 1957. 151 pp., diagrs., figs. 1,800 fr. In French.

The purpose of this treatise is to bridge the gap between the purely theoretical, rigorous treatment and the text written from the practical point of view. It is based on courses given by the author, who is Chief Test Pilot of S.N.C.A-Nord. Although primarily written for those engaged in various activities relating to the testing of aircraft, it is intended also for those, such as engineers or pilots, who are concerned in other ways with military, commercial, or personal aircraft.

Contents: (1) General. (2) Symmetric Rectilinear Horizontal Flight. (3) Symmetrical Rectilinear Climbing or Descending Flight. (4) Turning Flight or Flight with Vertical Maneuvers. (5) Take-Off and Landing. (6) Dissymmetric Flight. (7) Flight in Turbulent Air.

AUTOMATIC CONTROL

Nichtlineare Regelungsvorgänge; Vorträge gehalten bei einer Tagung des Fachausschusses Regelungsmathematik der Gesellschaft für angewandte Mathematik und Mechanik in Darmstadt am 8. September 1955. **(Nonlinear Control Processes;** Addresses Delivered at the Meeting of the Control Mathematics Division of the Society for Applied Mathematics and Mechanics, Darmstadt, September 8, 1955). Compiled by Wolfgang Hahn. Munich, Verlag R. Oldenbourg, 1956. 108 pp., illus., figs. DM 14.–. In German.

Contents: Das A-Kurven-Verfahren zur Berechnung nichtlinearer Regelvorgänge (The A-Curve Method for the Analysis of Nonlinear Control Processes), K. Magnus. Behandlung von Regelungsproblemen mit Hysteresis und Reibung nach der Methode der Beschreibungsfunktion (The Treatment of Control Problems with Hysteresis and Friction According to the Descriptive Function Method), J. M. L. Janssen and J. C. Vermeulen. Behandlung zweier Stabilitätsprobleme mit der zweiten Methode von Ljapunov (The Treatment of Two Stability Problems with Liapunov's Second Method), W. Hahn. Anwendung der Ljapunovschen Methode und des Verfahrens von Krylov-Bogoliubov auf ein technisches Beispiel (Application of the Liapunov Method and the Krylov-Bogoliubov Method to a Technical Example: Automatic Control of Aircraft), E. Pestel. Untersuchung eines nichtlinearen Regelkreises in einer mehrblättrigen Phasenebene (Investigation of a Nonlinear Control Circuit in a Multi-Loop Phase Plane), W. Haacke.

AVIATION FACILITIES

Aviation Facilities Planning; A Report by the President's Special Assistant, Edward P. Curtis. Washington, The White House, May 15, 1957. 51 pp., diagrs.

For Information on IAS Library Services, see page 105

Statements and opinions expressed in Book Reviews are to be understood as individual expressions and not necessarily those of the Institute.

The inability of the existing techniques of traffic control to handle the increasing volume of air traffic, particularly under adverse weather conditions, led the President of the United States in February, 1956, to appoint Mr. Curtis as Special Assistant for Aviation Facilities Planning. In this capacity he was made responsible for:

(1) The direction and coordination of a long-range study of the Nation's requirements for aviation facilities.

(2) The development of a comprehensive plan for meeting in the most effective and economical manner the needs disclosed by the study.

(3) The formulation of legislative, organizational, administrative, and budgetary recommendations to implement the comprehensive plan.

The report was completed and submitted to the President on May 10, 1957, and begins with the acknowledgment that American air space is a natural resource that is on the verge of exhaustion in terms of the system now in place for managing free and safe access to this resource. The crisis in the making is the consequence of the phenomenon by means of which the United States is becoming more and more an air community and by the continuation of an air traffic methodology that has been made obsolescent by the vehicle it was meant to serve. It is considered that there is actually no shortage of air space for any demand that can now be foreseen and that the means are at hand for developing a control system capable of coping with the complex mixture of civil and military traffic that now fills the air. To further this end, the report calls for an independent Federal aviation agency to consolidate all management functions necessary to support the common needs of military and civil aviation.

Contents: (1) Introduction. (2) Definition of Aviation Facilities. (3) Summary of the National Requirements Through 1975. (4) Summary of Plan for National Facilities. (5) Government Organization; The Interim Plan for Organization; a Permanent Organization for National Aviation. (5) Financing Aviation Facilities.

A Plan for Modernization of the National System of Aviation Facilities. Preston R. Bassett, Chairman, Systems Engineering Team, Office of Aviation Facilities Planning, The White House. Washington, May 6, 1957. 107 pp., diagrs.

This report presents a plan for meeting aviation facilities needs in the United States for the next two decades. After an examination of the traffic expected over this period, the report analyzes the operational desires of the users and discusses system design concepts that allow these desires to be satisfied. It concludes with a suggested initial configuration of a modern aviation facilities system and a plan of action to ensure the continued modernization of this system. Because airport capacity may become a limiting factor in the whole system, an appendix is devoted to a detailed analysis of airports.

Contents: (1) Introduction. (2) The Air Traffic 1957–1975. (3) National Aviation Policy. (4) Principles of Air Traffic Control: (a) Division of Airspace; (b) Minimum Requirements; (c) Flight Paths. (5) System Design Concepts: (a) Blocks; (b) Aircraft Position Information; (c) Navigation; (d) Communications; (e) Equip-

ment Standardization; (f) Data Processing; (g) Airports; (h) Air Defense and Air Traffic Control. (6) Techniques. (7) System Description. (8) Organization. (9) Plan of Action. (10) Conclusions. (11) Summary of Recommendations. Appendices: (a) System Engineering; (b) Principles of Air Traffic Control; (c) System Design Concepts; (d) Techniques; (e) Initial Configuration; (f) Airports.

COMPUTERS

Computing With Desk Calculators. Walter W. Varner. New York, Rinehart & Company, Inc., 1957. 108 pp., tables. $2.00.

Designed to help the user evolve personal computing techniques for his desk calculator, this general instruction manual for beginners also contains a helpful review of unusual and seldom used techniques for the experienced user of the computer. It is written primarily for persons employing machines to perform different calculations, such as cost estimating, evaluation of functions, interpolation, and statistics and describes the principal classes of desk calculators all of which have the same common basic computing features. Since it is often necessary to check double precision calculations performed on large-scale electronic macnines, the text includes considerable work on the fundamental operations on numbers larger than the capacity of a desk calculator. An elementary knowledge of calculus will be helpful in dealing with some of the material. The author is Head, Flight Simulation Laboratory and Computers, Convair Astronautics, A Division of General Dynamics Corporation.

DICTIONARIES

Russian-English Atomic Dictionary. Eugene A. Carpovich. Technical Dictionaries Co., Box 141, New York 31, N. Y., 1957. 317 pp. $12.

Prepared for English-speaking researchers who deal with Russian-language publications in the atomic field, Dr. Carpovich's work combines the functions of general language, polytechnical, and special dictionaries. Covering primarily nuclear science and nuclear technology, it contains over 23,000 Russian entries arranged in a single alphabetical list and numerous cross references referring to synonyms or near-synonyms, closely related or derived terms, and to different parts of speech, terms of different meaning, or antonyms. In addition, it contains many terms taken from theoretical, atomic, and molecular physics, physics of solids, crystallography, pure and applied mathematics, chemistry and chemical engineering, metallurgy and metallography, biophysics and radiobiology, and medicine and biology. Also included are miscellaneous terms used in computing, automatic control, electronics, library practice, publishing and printing, and similar fields.

ELECTRIC EQUIPMENT

The Physics of Electrical Contacts. F. Llewellyn Jones. Oxford, Clarendon Press; New York, Oxford University Press, 1957. 219 pp., illus., diagrs., tables. $5.60.

The primary purpose of this book is to explain the fundamental physical processes involved in the operation of electrical contacts and to describe investigations of the significant properties of the materials used in a contact. With emphasis on the basic physics rather than the design of any particular contact, the subject matter ranges over electron and ionization physics, the properties of thin films and semiconductors, and the behavior of metals at high temperatures. It includes a description of some recent research into the microphenomena of contact operation. Though intended in the main for research physicists and electrical engineers, the text is also suitable for undergraduate students. The author is Professor and Head, Department of Physics, University College of Swansea, University of Wales.

ELECTRONICS

Proceedings of the RETMA Symposium on Applied Reliability, University of Southern California, Los Angeles, December 19–20, 1956. Sponsored by the Engineering Department Radio-Electronics-Television Manufacturers Association. Engineering Publishers, Box 1151, New York 1, N.Y., 1957. 151 pp., illus., diagrs., tables. $5.00.

In addition to the papers delivered at the RETMA symposium, there is included a supplement entitled, "A General Guide for Technical Reporting of Electronic Systems Reliability Measurements." This guide was prepared by members of the Systems Reliability Analysis Task Group of RETMA's Electronic Applications Committee (Reliability).

Contents: Mechanical Reliability: Mechanical Reliability in Electronic Design, Arthur H. Kuriloff. Cosmic Ray Effects on Transistors, A. H. Drayner. *Information Feedback:* Limitations of Failure Reporting Systems, H. G. Fridell. Some Advantages of a Sampling System for Field Data Reporting, R. C. Schneider and N. E. Classon. Guide for Technical Reporting, George M. Armour. *Failure Feedback—Is It Effective?:* Effective Field Failure Feedback, R. L. Batts. *Component Evaluation and Usage:* Acceptable Airborne Radar Reliability Without Further Component Part Improvement, Russell H. Lindsay. Proper Application of Component Parts, Key to Reliability Improvement, Karl F. McCready. Electronic Components—Curse or Cure?, A. M. Okun. Heat Dissipation in Electronic Tubes, William D. Campbell. *Component Evaluation and Usage, II:* Airborne Electronic Equipment Effectiveness, Herbert G. Jacks. Trouble Correction in the Convair-San Diego Reliability Program, A. M. Small and R. A. Nichols. Design Techniques to Achieve Reliability in Inertial Sub-Systems, David L. Bjorndahl. Design Considerations of a 10-Watt Transistorized Servo Amplifier, Harold M. Bell.

Proceedings of the RETMA Symposium on Reliable Applications of Electron Tubes, Held at University of Pennsylvania, May 21–22, 1956. Sponsored by the Engineering Department, Radio-Electronics-Television Manufacturers Association. Engineering Publishers, Box 1151, New York 1, N.Y., 1956. 105 pp., diagrs., tables. $5.00.

Contents: Field Experience as an Aid to Reliable Equipment Design: Field Trial Techniques as a Tool to Improve Reliability and Life in Electron Tubes, L. F. Moose. Electron Tube Misapplication When Uncovered Through Field Surveillance, M. H. Norton. Defective Tubes—Manufacturer or User Responsibility?, R. B Wilson. *Circuit Session:* Keyed Phase Sensitive Demodulator, O. Berger. Design of Reliable Flip-Flop, H. W. Boyd. Series String Applications of Electron Tubes (Commercial and Military), R. G. Rauth. Application of Low-Mu Triodes to Series Regulators, S. Rubin. *Panel Session:* Can Tube Specifications Produce Reliable Equipment?, W. R. G. Baker, M. A. Acheson, N. W. Aram, J. M. Bridges, F. Q. Gemmill, W. C. Kirk, and C. G. Walance. *Planning for Reliable Design:* Designing for Reliability Through the Proper Application of Tubes, C. M. Ryerson. Application Techniques Leading to Reliable Circuit Performance, J. J. Hofler. Mathematical Tools for Reliable Design, E. E. Brewer. *Receiving Tubes:* JETEC Industry Standardization Towards Reliability, C. E. Coon. Tube Acceptance Specifications for Television Applications, R. G. O'Fallon. Reliability in Dissimilar Section Tubes, R. W. Slinkman. Receiving Tube Reliability Studies, G. H. Gage, Jr.

Semiconductor Abstracts: Abstracts of Literature on Semiconducting and Luminescent Materials and Their Applications, Vol. 3, 1955 Issue. Compiled by Battelle Memorial Institute; Sponsored by the Electrochemical Society, Inc. New York, John Wiley & Sons, Inc., 1957. 322 pp. $10

The increased use of semiconductors and luminescent materials in new products has led to a tremendous expansion in the literature covering the subject matter in these fields. This years' compilation of abstracts has been prepared jointly by members of the Solid State Devices Division and the Physical Chemistry Division of Battelle Memorial Institute and includes material taken from the principal abstract journals and papers presented at technical society meetings. Important results are included in most of the abstracts, thereby reducing the necessity of securing the original article, and special efforts were made to include numerical results whenever possible. More than 1,200 items are abstracted and classified by subject under the broad headings of Germanium; Silicon; Carbon, Selenium, and Other Elemental Semiconductors; Intermetallics; Sulfides, Selenides, and Tellurides; Oxides; Halides; Arsenates, Phosphates, and Tungstates; Organics; and Theory. Alphabetic subject and author indexes are provided.

The Cathode Ray Oscilloscope, Circuitry and Practical Applications. J. Czech. Translated from the German by G. E. Luton. (Philips' Technical Library.) New York, Interscience Publishers, Inc., 1957. 340 pp., illus., diagrs. $8.50.

The scientist and engineer just becoming acquainted with the technique of oscillography will find in this work the results of 20 years' experience dealing with a wide range of practical problems involving the oscilloscope. Details are given for the construction, use, and applications of the instrument, with more than 600 original oscillograms by the author used to point up its range of capabilities. The concluding chapters of the book are devoted to directions for building a simplified oscilloscope, a high-precision instrument, and a simple time-base expansion unit.

Contents: Part 1—The Cathode Ray Oscilloscope: (1) The Cathode Ray Oscilloscope. (2) The Cathode Ray Tube. (3) Power Supply. (4) The Time Base Generator. (5) Deflection Amplifiers. *Part 2—General Measuring Technique:* (6) Taking the Oscilloscope into Service; Adjustment Procedure. (7) Simple Amplitude Measurement. (8) The Oscilloscope as Null Indicator in AC Bridge Circuits. (9) The Display of Hysteresis Loops. (10) The Uses of Intensity Modulation. (11) Phase Measurements. (12) Frequency Measurements. *Part 3—Practical Examples:* (13) Recording the Waveforms of Luminous Flux, Current and Voltage of Fluorescent Lamps. (14) Investigating Switching Phenomena on Electric Light Bulbs. (15) Investigations on Television Receivers. (16) Measuring the Action of "Between-Lens" Shutters. (17) Recording the Waveforms of the Luminous Flux and Ignition Current of Flash-Bulbs. (18) Investigations on Flash-Bulb Synchronizers. (19) Measuring the Travel Time and Investigating Line Matching Conditions with Pulsed Voltages. *Part 4—Circuit-Designing:* (20) Small Oscilloscope. (21) Special Duty Oscilloscope "FTO-2." (22) Simple Time Base Expansion Unit for Displaying Phenomena with the Mains Frequency and Mains-Coupled Television Pulses.

GEOPHYSICS

Elastic Waves in Layered Media. W. Maurice Ewing, Wenceslas S. Jardetzky, and Frank Press. (Lamont Geological Observatory Contribution No. 189.) New York, McGraw-Hill Book Company, Inc., 1957. 380 pp., diagrs. $10.

Investigation on earthquake seismology, underwater sound, and model seismology form the basis of this work which covers both the experimental and theoretical aspects of the theory of wave propagation in layered media as it relates to seismology, geophysical prospecting, and problems of acoustics and electromagnetism. Topics under discussion include observations of surface waves from explosions and earthquakes, flexural waves in ice, deductions concerning the structure of the earth's crust, model studies using ultrasonic waves, underwater sound propagation in shallow water, and SOFAR sound propagation. Numerous references accompany each chapter and form a comprehensive and systematic biblio-

graphy of the world literature for the main topics discussed.

W. M. Ewing and W. S. Jardetzky are both with the Lamont Geological Observatory of Columbia University; F. Press is Professor of Geophysics, California Institute of Technology.

Contents: (1) Fundamental Equations and Solutions. (2) Homogeneous and Isotropic Half Space. (3) Two Semi-Infinite Media in Contact. (4) A Layered Half Space. (5) The Effects of Gravity, Curvature, and Viscosity. (6) Plates and Cylinders. (7) Wave Propagation in Media with Variable Velocity. Appendix A. Method of Steepest Descent. Appendix B. Rayleigh's Principle.

HYDRAULIC EQUIPMENT

Aircraft Hydraulic Design. George R. Keller. Edited by Allan E. Morris. Cleveland, Applied Hydraulics Magazine, 1957. 130 pp., illus., diagrs., tables. $4.50.

Designers of industrial equipment, as well as aircraft engineers, will find material of value in this treatment of hydraulic component and system design for high-speed piloted aircraft and missiles. The book covers various aspects of the subject in three broad sections: basic theory treating properties of aircraft fluids, hydromechanics, and fluid flow through tubing; design of system components including actuators, valves, pumps, accumulators, transmission lines, and seals; and hydraulic power servos and high-temperature hydraulic problems. The chapter on high-temperature hydraulics outlines progress in fluids, seals, springs, metals, and other critical components and indicates future developments and techniques.

The author is Group Leader, Flight Control Engineering Department, Autonetics Division, North American Aviation, Inc. Mr. Morris is Associate Editor, *Applied Hydraulics* magazine.

MAGNETOHYDRODYNAMICS

Magnetohydrodynamics. T. G. Cowling. New York, Interscience Publishers, Inc., 1957. 115 pp., diagrs. $3.50.

While the principal emphasis in this tract is on the geophysical and astronomical applications of magnetohydrodynamics, the author points out that its engineering aspects have begun to be recognized, and he expresses the hope that this publication may assist in expediting developments in both fields.

Magnetohydrodynamics assumes an electrically conducting medium, which may be a liquid or an ionized gas. Both can be treated in a common theory if the ionized gas can be regarded as a continuous fluid; this is normally assumed to be the case in the present book. The equations appearing in the text are the ordinary electromagnetic and hydrodynamic equations, modified to take account of the interaction between the motion of the conducting fluid and the magnetic field, thus some knowledge of these equations is required of the reader. Vector methods are freely used, including transformations involving the curl and divergence of vectors, and expressions in terms of cylindrical polar coordinates. Dr. Cowling, Professor of Applied Mathematics, Leeds University, has supplied numerous references to the most important papers on the subject covered by each chapter.

Contents: (1) General Ideas and Simple Applications. (2) Magnetohydrostatics. (3) Wave Motion. (4) Magnetic Fields and Instability. (5) Dynamo Theories. (6) Ionized Gases.

MATERIALS

Plansee Proceedings, 1955; Sintered High-Temperature and Corrosion-Resistant Materials. Papers Presented at the Second Plansee Seminar, "De Re Metallica," Held June 19–23, 1955, Reutte/Tyrol. Reutte/Tyrol, Metallwerk Plansee G.m.b.H.; London, New York, Pergamon Press, 1956. 472 pp., illus., figs. $11.

The first Plansee Seminar, held in 1952, covered the entire field of powder metallurgy. This second seminar is restricted to a more limited

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field: sintered high-temperature and corrosion-resistant materials.

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In consideration of these viewpoints, the papers collected in these *Proceedings* have been classified in four parts. The first part deals with theoretical problems. The second, and largest, part is concerned with the most promising metallic hard materials of the type of the refractory carbides, borides, and silicides and the special products prepared on the basis of these materials. In the third part the refractory transition metals and their alloys are discussed. The fourth part collects the papers on combinations of metallic and nonmetallic components. Of the 38 papers published, half are in German, 15 are in English, and four are in French.

Physics of Non-Destructive Testing; With Particular Reference to Some of the New Aspects. (British Journal of Applied Physics, Supplement No. 6.) London, The Institute of Physics, 1957. 71 pp., illus., diagrs. 25*s*.

Contents: Some Aspects of the Mechanical Testing of Non-Metallic Solids, H. Kolsky. Symposium on Optical and Surface Methods of Non-Destructive Testing, S. Tolansky, R. W. B. Stephens, and O. S. Heavens. The Potentialities of X-Ray Diffraction Studies in Non-Destructive Testing, J. R. Rait and H. S. Peiser. Symposium on Principles of Penetrant Methods, H. L. Carson, W. G. Cook, and R. Schnurmann. Magnetic Properties and the Structure of Metals, W. Sucksmith. Principles and Applications of Nuclear Magnetic Resonance, L. E. Drain. Optical Fluorescence in Non-Destructive Testing, W. A. Runciman. The Effects of Penetrating Radiations on Materials, S. F. Pugh. Physical Methods in Medical Diagnosis, C. B. Allsopp. The Detection of Fatigue in Metals, R. F. Hanstock. Structural Changes and Energy Dissipation During Fatigue in Copper, N. Thompson and N. J. Wadsworth. Measurement of Elastic Constants by the Ultrasonic Pulse Method, M. F. Markham. The Testing of Fibres and their Molecular Structure, P. T. Barrett. Subject Index. Name Index.

The Chemistry of Organometallic Compounds. Eugene G. Rochow, Dallas T. Hurd, and Richard N. Lewis. New York, John Wiley & Sons, Inc., 1957. 344 pp., diagrs., tables. $8.50.

This comprehensive, unified coverage of the theoretical, factual, and practical aspects of organometallic compounds offers a survey of the field up to 1956 and presents a review of the structure and physical properties, the preparation, chemical reactions, and application of these compounds. The subject matter has been organized on the basis of the general properties of the carbon-metal bond; electronegativity and bond polarity have been used freely as indicative of the type of organometallic compound to be expected in a given instance. Topics of interest include sandwich compounds, bridge compounds, fluorinated organometallic compounds, organometallic complexions, the new pentaalkyl compounds of the group 5 elements, organometallic compounds in anionic polymerization—especially the "Ziegler process" for making polyethylene, and the typical as well as "abnormal" reactions with organic compounds.

MATHEMATICS

Cours de Mathématiques (A Course in Mathematics). J. Bass. Paris, Masson et Cie., 1956. 916 pp., figs. 8500 fr. In French.

This book represents, with certain additions, the material taught by the author at the Ecole Nationale Supérieure de l'Aéronautique and at the Ecole Nationale Supérieure des Mines, Paris. It is not a treatise on applied mathematics, nor does the reader need to have previous technical knowledge. It is rather an aid to the acquisition of new mathematical knowledge that can ultimately be used in the study of mechanics, hydrodynamics, the resistance of materials, general physics, and electricity. Each chapter is followed by an annotated bibliography and exercises. One chapter is devoted to the theory and practice of common mechanical integrators (planimeters, integraphs, harmonic analyzers) and another to nomography and nomograms.

Contents: (1) Linear Algebra. (2) Simple Integrals. (3) Functions Defined by Series or Integrals. (4) Curves, Curvilinear Integrals, Applications. (5) Surfaces, Multiple Integrals, Applications. (6) Analytic Functions. (7) Differential Equations and Systems. (8) Equations with Partial Derivatives, Potentials. Appendix A: Calculus of Variations. Appendix B: Nomograms. Formulas. Index of Mathematicians Cited. General Bibliography. Alphabetic Subject Index (35 pages).

An Introduction to Diophantine Approximation. J. W. S. Cassels. (Cambridge Tracts in Mathematics and Mathematical Physics, No. 45.) Cambridge, University Press; New York, Cambridge University Press, 1957. 166 pp. $4.00.

In this introduction to a branch of pure mathematics, the beginner will find a survey of the present state of knowledge concerning Diophantine approximation; the expert will find much material that is new in form or substance. Little more than the rudiments of number theory is required for comprehension by an undergraduate, and for such a reader the tract is self-contained, except that the elements of Lebesgue theory and of algebraic number theory are presupposed in the last two chapters. Much of the book deals with developments since 1936, and there is a useful select bibliography which refers to the most recent publications in this field. The author is a Fellow of Trinity College, Cambridge, and Lecturer in Mathematics in the University of Cambridge.

Contents: (1) Homogeneous Approximation. (2) The Markoff Chain. (3) Inhomogeneous Approximation. (4) Uniform Distribution. (5) Transference Theorems. (6) Rational Approximation to Algebraic Numbers. Roth's Theorem. (7) Metrical Theory. (8) The Pisot-Vijayaraghavan Numbers.

METEORS

Meteors. Symposium on Meteor Physics, July, 1954, Jodrell Bank Experimental Station, University of Manchester. Edited by T. R. Kaiser. (Journal of Atmospheric and Terrestrial Physics, Special Supplement, Vol. 2.) London, New York, Pergamon Press, 1955. 204 pp., illus., diagrs., tables. $8.50.

The thirty-nine papers published in this volume were presented by delegates from ten countries, including the United Kingdom, Czechoslovakia, the U.S.S.R., and the United States. They cover the physical problems of meteors and their interaction with the terrestrial atmosphere. Specific astronomical questions are also discussed, and the volume concludes with reviews of current and future research programs in various countries especially in relation to the International Geophysical Year.

Contents: Heat Transfer and the Ablation Process in Meteors, R. N. Thomas. The Nature of Meteoric Radiation, A. F. Cook. On Meteor Luminosity and Ionization, F. L. Whipple. Meteor Ionizing and Luminous Efficiencies, S. Evans and J. E. Hall. Collisions Between Heavy Particles, B. L. Moiseiwitsch. Atomic Collisions in Meteor Trails, D. W. Sida. Meteor Excitation, Ionization and Atomic Luminous Efficiency, E. J. Opik. The Masses and Structure of Meteors, E. J. Opik. Fragmentation as the Cause of the Faint-Meteor Anomaly, L. G. Jacchia. Relationship Between Masses and Visual Magnitudes of Meteors, H. K. Kallman. The Interpretation of Radio Echoes from Meteor Trails, T. R. Kaiser. The Meteoric Head Echo, D. W. R. McKinley. Observations of Polarization Effects in Radio Echoes from Meteor Trails, E. R. Billam and I. C. Browne. Scale Height in the Ionosphere Deduced from Meteors, F. Link. Contribution of Meteoritic Material to the Atmospheric Absorption, F. Link. Atmospheric Corrections to Meteor Velocities and the Atmosphere Density Gradient, Z. Ceplecha. Atmospheric Pressures and Scale Heights from Radio Echo Observations of Meteors, S. Evans. Winds in the Lower E-Region, J. S. Greenhow and E. L. Neufeld. Meteoric Influences on the Sporadic E-Layer, L. Neuzil. Meteor Ionization and the Night-Time E-Layer, M. Nicolet. Meteor Ionization in the E-Region, M. Dubin. The Incident Flux of Meteors and the Total Meteoric Ionization, T. R. Kaiser. Physical Theory of Meteors and the Study of the Structure of the Complex of Meteor Bodies on the Basis of Visual Meteor Observations, B. J. Levin. Origin of the Zodiacal Cloud, F. L. Whipple. Diffuse Matter in the Solar System, H. Siedentopf. A New Technique for Eclipse Observations of the Solar Corona, C. W. Allen. On the Velocities and Orbits of Meteors, Fireballs, and Meteorites, F. L. Whipple and R. F. Hughes. Radio Measurements of Individual Meteor Orbits, J. G. Davies. On the Activity of Telescopic Meteors, Margaret Kresak and L. Kresak. The Direction Distribution of Telescopic Meteors, L. Kresak. On Some Recently Observed Fireballs, J. van Diggelen and C. de Jager. Meteor Streams at Early Stages of Evolution, M. Plavec. The Giacobinid Meteor Shower, J. G. Davies. Sikhote-Aline Meteorite, V. G. Fessenkov. Meteors and the International Geophysical Year, A. C. B. Lovell. Meteor Studies in the Soviet Union, V. V. Fedynsky. Meteor Investigations at the Stalinabad Astronomical Observatory, L. A. Katassev. Radio-Echo Observations of Meteors in the Southern Hemisphere, A. A. Weiss. Radar Meteor Research in New Zealand, C. D. Ellyett.

PRODUCTION

The Casting of Steel. Edited by W. C. Newell. New York, Philosophical Library, 1957. 599 pp., illus., diagrs., tables. $27.50.

Steel founders, metallurgical students, and engineers will find this profusely illustrated work a reliable guide to the technical aspects involved in the production of steel castings. The scope of the book includes basic principles and their applications, practical methods for quality control, testing and inspection, and economic considerations such as the mechanization of the steel foundry and the reclamation of molding sands. The material of the text is composed of contributions by fifteen leading British authorities in the field and has been edited by the former Head of Steel Castings Division, British Iron and Steel Research Association.

Contents: (1) Properties of the Liquid Metal. (2) The Mechanism of Solidification. (3) The Melting Process. (4) The Use of Refractories. (5) Pattern Making. (6) Mould Preparation and Coremaking. (7) Casting into Sand Moulds. (8) Centrifugal Formation of Castings. (9) The Investment Casting Process. (10) The Heat Treatment and Properties of Steel Castings. (11) Mechanical Testing—Physical Properties—Specifications. (12) Radiography. (13) Non-Destructive Testing (Methods Other Than Radiography). Index.

PUMPS

Pump Selection and Application. Tyler G. Hicks. New York, McGraw-Hill Book Company, Inc., 1957. 422 pp., illus., diagrs. $8.50.

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ROTATING WING AIRCRAFT

Proceedings of the Thirteenth Annual National Forum, Washington, May 8-11, 1957. New York, American Helicopter Society, 1957. 139 pp., illus., diagrs., tables. $7.50.

Contents: Helicopter Design and Development: Metal Rotor Blade Development, George H. Linnabery. Closing the Loop on Automatic Stabilization Equipment, Walter Gerstenberger and Edward S. Carter, Jr. Test Experience With the T58 Engine, Newell N. Davis. T53 Flight Test and Test Stand Results, Leroy A. Howard. *VTOL Aircraft Design and Development:* The Limitations of a Wing for Low Speed Flight, John B. Nichols. Compromises Associated With VTOL and STOL Propellers, Robert A. Rogers. Military Aspects of VTOL Aircraft Development, John L. Klingenhagen. Designing for Crash Survival in VTOL Aircraft, A. Howard Hasbrook. Stability and Control of Propeller-Driven Transport VTOL Airplanes, Robert H. Kirby. *Theory and Test:* Determination of Flapwise Load Distribution on a Rotor Blade from Measured Strain and Rotor Data, Herbert Somerson. Physical Interpretation of Helicopter Chordwise Vibration, William B. Gevarter. On a Type of Low-Advance-Ratio Blade Flapping Instability of Three-or-More-Bladed Rotors Without Drag Hinges, Kurt H. Hohenemser. Theoretical and Experimental Study of the Coupled Flap-Bending and Torsion Aero-Elastic Vibrations of a Helicopter Rotor Blade, Peter F. Leone. A Parametric Analysis Method for Rotor Blade Structural Design, Alex Berman. *Operations and Navigation:* Helicopter Transport Operations in the North, Oscar N. Tibbetts. Application of the Decca Navigation System as an Approach and Landing Aid, Harry W. Mitchell. The French Army Helicopter Operation in Algeria, Thomas R. Pierpoint and Louis J. Geier.

Hubschrauberverkehr (Helicopter Transportation). Voraussetzungen und Möglichkeiten des Hubschrauberverkehrs (Assumptions and Possibilities of Helicopter Transportation), C. Pirath. Raumlage und Gestaltung von Hubschrauberflughäfen (The Location and Design of Heliports), Carl E. Gerlach. (Suttgart, Technische Hochschule, Verkehrswissenschaftliches Institut, Forschungsergebnisse, Heft 17.) Berlin, Göttingen, Heidelberg, Springer-Verlag, 1956. 60 pp., diagrs., figs. DM 12.–.

Dr. Pirath's study opens with a summary history of helicopter design and a brief discussion of safety aspects. He then takes up in detail helicopter performance (as it is related to a transportation system and to economic factors), heliports, and subsidies. His conclusions concern the suitability of the helicopter for passenger, freight, and mail operations.

The paper by Dr. Gerlach is divided into nine parts: general operating aspects; the possibilities of a special purpose location; obstacles to approaching and departing flights; dimensions and grouping of the operating surfaces; movement control problems and separation of airways for helicopters and fixed-wing aircraft; operating efficiency of heliports; load capacity and construction of take-off and landing surfaces, including turf, fabricated surfaces, roofs, platforms, and drainage; cost factors of the various types; and summary of conclusions.

SAFETY

Survey of Research Projects in the Field of Aviation Safety; Sixth Annual Supplement, January, 1957. New York, Los Angeles, The Daniel & Florence Guggenheim Aviation Safety Center at Cornell University, 1957. 114 pp. $2.00.

The seventh in a series of annual surveys listing information on nonclassified research conducted in various fields affecting aviation safety, this report contains several hundred projects not formerly listed. In addition, the status of all previous projects was checked, and the descriptive statements revised to accord with information obtained. The section on "Completed Projects" has been enlarged, and, to obtain the full record of any particular subject, the completed project list should be examined. In the list of projects forming the major portion of this report, entries for each item include the title, a concise description of the nature of the problem under investigation, the sponsoring agency and its location, and a G-number which refers to the project sheet in the files of the Aviation Safety Center. This list of projects is arranged by main and subheadings according to the subject and topics involved.

STRUCTURES

Proceedings of the Society for Experimental Stress Analysis, Vol. 14, No. 2. Edited by C. V. Mahlmann and W. M. Murray. Cambridge, Mass., The Society, 1957. 174 pp., illus., diagrs., tables. $6.

Contents: Stress Analysis in the Design of a Mobile Home, G. M. McClure and E. D. Abraham. On an Electrical Analogy Method for the Separation of Principal Stresses along Stress Trajectories, P. S. Theocaris. Potentialities of the Impact Machine for Producing High Accelerations, M. Kornhauser. Letter to the Editor: "Individual Strain Gage Desensitization," P. K. Stein. The Northrop Load Maintainer and Load Proportioner System, D. M. Cole, Jr., and J. A. Ralls. A Transistorized AM-FM Radio Link Torque Telemeter for Large Rotating Shafts, W. R. Campbell and R. F. Suit, Jr. Experimental Research on Aircraft Structures at Elevated Temperatures, J. N. Kotanchik. Dynamic Photoelasticity by Means of Streak Photography, M. M. Frocht, P. D. Flynn, and D. Landsberg. Developments in the Grid Method of Experimental Stress Analysis, A. J. Durelli and W. F. Riley. The Brittle Lacquer Technique of Stress Analysis as Applied to Anisotropic Materials, J. H. Cunningham and J. M. Yavorsky. Use of Creep to Determine the Sum of the Principal Stresses in Two-Dimensional Problems, A. J. Durelli and W. F. Riley. External Strain-Gage Instrumentation for Transient Elevated Temperatures, R. C. Geiger and I. Sherlock. Protection of Underwater SR-4 Strain-Gage Installations on Tunnel Liner of a Hydroelectric Development, R. S. Barker and J. B. Murtland. Magnetostrictive Effects in Wire Strain Gages, I. Vigness. Minimizing Creep of Paper-Base SR-4 Strain-Gages, M. McWhirter and B. W. Duggin. A Differential Torsion Testing Machine, N. H. Cook. Experimental Determinations of Stresses in the Vicinity of Pipe Appendages to a Cylindrical Shell, F. J. Mehringer and W. E. Cooper.

Anisotropic Plates. S. G. Lekhnitskii. (Translation of *Anizotropnye Plastinki*, Moscow, 1947.) Translated by Elbridge Z. Stowell. (Contributions to the Metallurgy of Steel, No. 50.) New York, American Iron and Steel Institute, June, 1956. 354 pp., diagrs., tables.

This systematic exposition of the problems connected with the deformation and strength of anisotropic plates was written to serve as an aid to engineers, aircraft constructors, and physicists. The work reflects three basic themes: the generalized state of plane stress for an anisotropic plate, the bending of anisotropic plates, and the stability of anisotropic plates. Most of the practical solutions given in the text originate with the author and represent the result of 20 years of work on the theory of elastic anisotropic plates. The bibliography, which lists papers, journals, and books by Soviet, French, German, and English authors, summarizes the extent and limits of the literature available at the time of publication of the original work (1947).

Contents: (1) Basic Equations of the Theory of Elasticity for an Anisotropic Body. (2) The

Plane Problem of the Theory of Elasticity for an Anisotropic Body. (3) The Bending of Anisotropic Beams and Curved Bars. (4) Stress Distribution in an Infinite Elastic Medium. (5) Stress Concentration Around an Elliptical and a Circular Hole. (6) Stress Distribution in an Elliptical and in a Circular Plate. (7) An Approximate Case of Stress Determination in a Plate with Weak Anisotropy. (8) Theory of the Bending of Anisotropic Plates. (9) Bending of Plates under Normal Load. (10) Bending of Plates under Loads Distributed Along the Edge. (11) Transverse Oscillations of a Plate. (12) Fundamentals of the Theory of Plate Stability. (13) Stability of a Rectangular Plate and of a Strip under Distributed Load. (14) Stability of Plates Compressed by Concentrated Forces. (15) Stability of Plates Reinforced by Stiff Ribs.

THERMODYNAMICS

Principles of Chemical Engineering Thermodynamics. Ernest D. Wilson and Harold C. Ries. New York, McGraw-Hill Book Company, Inc., 1956. 376 pp., diagrs., tables. $7.50.

This text is written specifically for an undergraduate course in the chemical-engineering field and presents thermodynamics as a tool and a method of approach to the solution of industrial problems. The various topics of discussion include the states and properties of matter, the first and second laws of thermodynamics, the handling and compression of fluids, thermochemical effects, graphical presentation and interpretation, steam power plants, refrigeration, thermodynamic potential functions, real gases versus ideal gases, phase equilibria, and chemical equilibrium. The book contains many fully solved illustrative problems, and a flow sheet is provided showing part of a hypothetical plant which relates to problems appearing throughout the text. Worth noting is the use of a practical, semiempirical method of estimating free energies of formation of solid compounds from solubility data.

The authors are respectively Professor of Chemical Engineering and Chemistry, Worcester Polytechnic Institute, and a member of Emeryville Research Center, Shell Development Company.

VIBRATION

Kolebaniia Uprugikh Sistem (Vibrations of Elastic Systems). A. P. Filippov. Kiev, Izdatel'stvo Akademii Nauk Ukrainskoi SSR, 1956. 322 pp., figs. In Russian.

This volume reviews problems connected with the linear vibrations of elastic systems and introduces methods of calculation which are suitable for practical application. Emphasis is placed on the calculation of damping, and a large part of the book is devoted to the calculation of free and forced vibrations of rods and rod systems (beams, shafts, two- and three-dimensional frames, supports, etc.). The author surveys the vibrations of circular plates, as well as of rectangular plates without reinforcement and with reinforcement in one or two directions. A solution is given to the problem of the free vibrations of a closed cylindrical shell, the ends of which are simply supported or rigidly fixed. Also investigated is inelastic impact on beams and on circular and rectangular plates resting on an elastic foundation. The book is intended for engineers, graduate students, and scientific workers. The 143 references in the bibliography are principally to Russian sources.

Einführung in die Berechnung Mechanischer Schwingungen, Band 1. (Introduction to the Calculation of Mechanical Vibrations, Vol. 1.) A. Weigand. Berlin, VEB Verlag Technik, 1955. 123 pp., figs. In German.

An introduction to the quantitative investigation of periodic processes in various branches of applied physics and technology as they can be described by the concepts of classical mechanics. The fundamentals of differential and integral calculus and elementary knowledge of differential equations are prerequisites.

Contents: Vibrations with One Degree of Freedom. (1) Introduction; The Concept of Vibration. (2) Free Vibrations with a Linear Characteristic. (3) Free Undamped Vibrations with a Curved Characteristic. (4) Forced Vibrations with a Linear Characteristic. (5) Forced Vibrations with a Curved Characteristic. (6) Concluding Remarks on the First Volume. Literature. Subject Index.

WIND TUNNELS

Optical Methods for Examining the Flow in High-Speed Wind Tunnels. Part 1, Schlieren Methods, D. W. Holder and R. J. North. **Part 2, Interferometer Methods,** George P. Wood. (AGARDograph No. 23). Paris, NATO, AGARD, November, 1956. 148 pp., illus., diagrs., tables. Distributed in U.S. by NACA, Washington.

This is one of a series of Wind Tunnel AGARDographs concerned with wind-tunnel design, operation, and test techniques and was prepared with the cooperation of the Air Force Office of Scientific Research of the Air Research and Development Command, USAF. The paper reviews the present state of knowledge concerning the use of schlieren, direct-shadow, and interferometer techniques for visualizing and photographing the flow in high-speed wind tunnels. Emphasis is placed on the most widely used techniques, but brief details are also given of methods which are in an early stage of development or which are useful only in a limited range of investigations. Information on suitable light sources and photographic materials is included.

The authors of *Schlieren Methods* are with the National Physical Laboratory, Teddington, England, and Mr. Wood is with the NACA.

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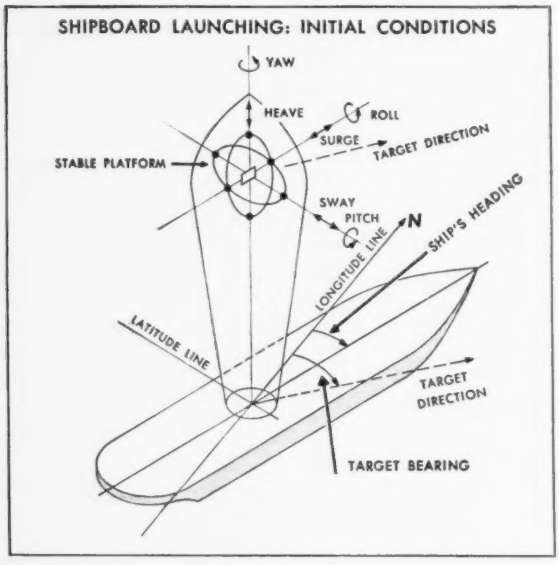

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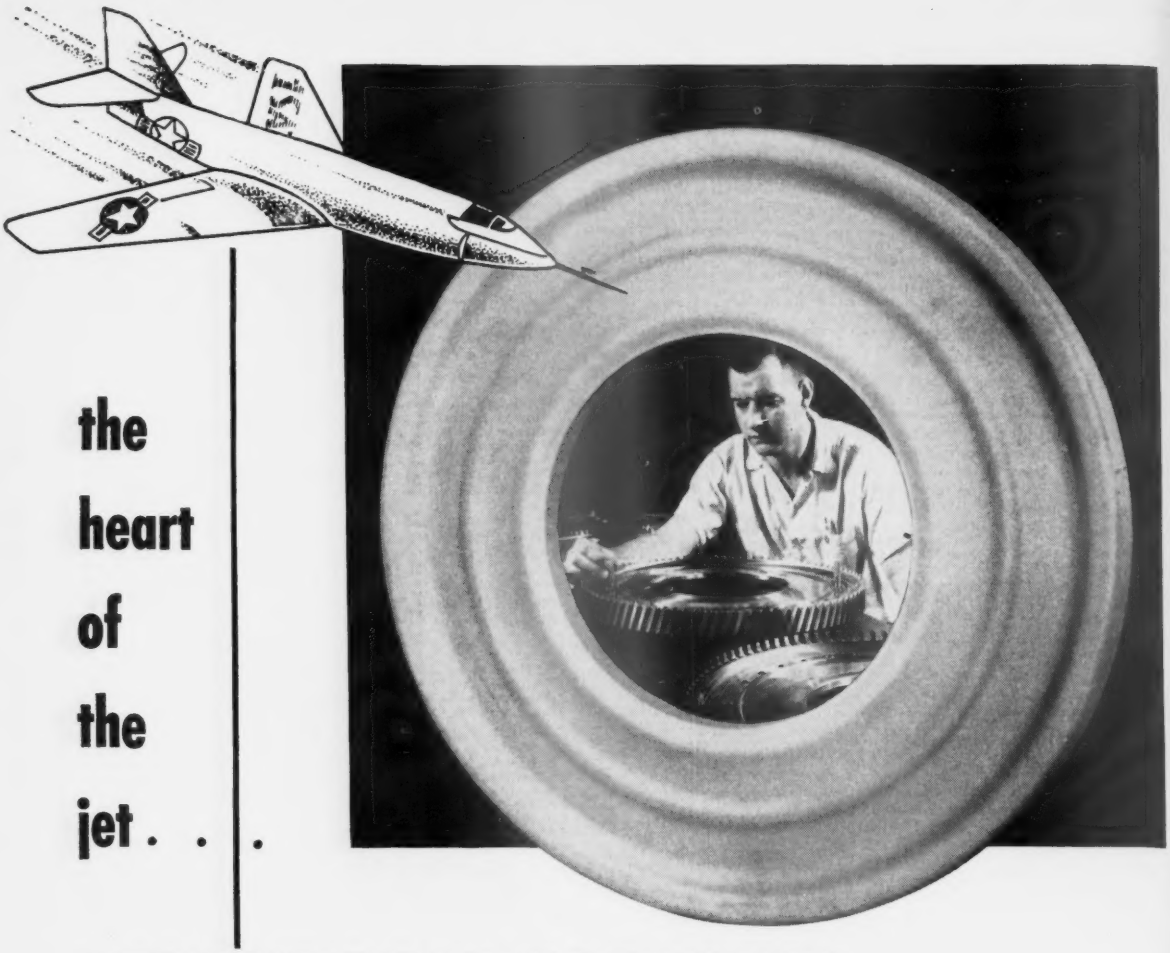

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"Copper & Copper-Alloy Specifications Index." 28-page booklet B-34 gives complete specification data on company's products. *The American Brass Co.*, Dept. RS, Waterbury 20, Conn.

"Ceramicite." Ceramic material for hermetic seal applications at high temperatures; bonds physically to most stainless steels. *Consolidated Electrodynamics Corp.*, 300 N. Sierra Madre Villa, Pasadena, Calif.

"Pyroceram" Crystalline Materials Made From Glass. These tough, heat-resistant substances are claimed to be harder than steel, lighter than aluminum, and nine times stronger than plate glass. *Corning Glass Works*, Corning, N.Y.

Sandwich-Type Load-Carrying Missile Structures. Fabricated of reinforced plastics; designed to withstand the same loads and temperatures as a similar metal component. *Narmco, Inc.*, 1882 Moore St., San Diego, Calif.

Fabrication of Stainless Steel & High-Temperature Alloys. 16-page brochure reviews company's history and operating methods in this field. *Portland Copper & Tank Works, Inc.*, 80 Second St., South Portland, Me.

Study on Solvent & Chemical Resistance of Butyl Rubber. A 16-page booklet. *Thiokol Chemical Corp.*, 780 N. Clinton Ave., Trenton 7, N.J.

"Niphos" Thin Nickel-Alloy Coating. Protects aircraft parts from corrosion and abrasion; resists peeling and flaking. *Tube Reducing Corp.*, Wallington, N.J.

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200-Volt A.C., Three-Phase, 400-Cycle Servomotor. For intermittent duty applications requiring a maximum of 1/4 hp. *American Bosch Div.*, American Bosch Arma Corp., Springfield 7, Mass.

Model AN-00007 Hermetically Sealed Sampling Switch. Designed for use in a target designation system for fighter aircraft. *Applied Science Corp. of Princeton*, Princeton, N.J.

Squib-Actuated Switch for Aircraft & Missiles. Provides four sets of contacts furnished in any combination of normally open and normally closed positions; extremely rugged. *Atlas Powder Co.*, Parke-Thompson Ordnance Section, 9404 Watson Rd., St. Louis 19, Mo.

Single-Acting Self-Locking Quick-Release Pins. Bulletin ADI 1268-257 gives "Pip Pin" engineering data. *Aviation Developments Inc.*, P.O. Box 391, Burbank, Calif.

Linear Accelerometers. Bulletin LF-MF-6-57 describes units suitable for direct recording of maneuvering or low-frequency accelerations of aircraft, missiles, and other moving vehicles. *B & F Instruments Inc.*, 4732 N. Broad St., Philadelphia 41, Pa.

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Servomotor-Rate Generator. Data sheet 869 describes a size 18, 115-volt, 400-cycle unit, Model 18MG 490/460. *Helipot Technical Information Service*, Newport Beach, Calif.

Size 11, 115-Volt, 400-Cycle Servomotor-Rate Generator. Data sheet 872 gives details of Model 11 MG 460/460. *Helipot Technical Information Service*, Newport Beach, Calif.

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"Vac-Tite" Compression Multi-Headers & Plugs. 16-page catalog condenses over 10,000 different types of hermetic seals. *Hermetic Seal Corp.*, Dept. AER, 29 S. 6th St., Newark 7, N.J.

Model 815 Stabilized Microwave Oscillator. Covers a new tuning range from 9,000 to 10,500 mc. *Laboratory for Electronics, Inc.*, 75 Pitts St., Boston 14, Mass.

Magnetic Low-Level D.C. Signal Amplifier. Capable of operating from a 28-volt aircraft or missile system. *Magnetic Research Corp.*, Sales Engineering Dept., 3160 W. El Segundo Blvd., Hawthorne, Calif.

High-Power Flange-Mounted Waveguide Pressure Window. For use in radars operating in the 35-kmc. frequency range requiring pressure seals to prevent waveguide or magnetron RF breakdown. *Microwave Associates, Inc.*, Burlington, Mass.

High-Temperature Miniature Motor-Tach Generator. Type 10-MTG-6229-15 operates continuously in an ambient temperature range from −55° to +125°C. *John Oster Mfg. Co.*, Avionic Div., 1 Main St., Racine, Wis.

High-Temperature "Klixon" Sine Switch. This hermetically sealed unit is designed to operate continuously at temperatures as high as 375°F. *Spencer Thermostat Div.*, Metals & Controls Corp., Attleboro, Mass.

Quick-Filming Aviation Brushes. Claimed to require no sea-level "break-in" filming run. *Stackpole Carbon Co.*, St. Marys, Pa.

Automatic Voltage Regulator for High-Frequency Use. Type 1EH5101 for 400-cycle, single-phase service gives instantaneous correction of line voltage variations. *The Superior Electric Co.*, Dept. 1EH, 83 Laurel St., Bristol, Conn.

High-Frequency Variable Transformers. 28-page bulletin P257H gives complete data on "Powerstat" units. *The Superior Electric Co.*, Dept 257, 83 Laurel St., Bristol, Conn.

"Powerstat" Variable Transformers for High-Frequency Duty. Designed for single- and three-phase 400/800-cycle operation; operate at ambient temperatures of −55° to +40°C. at full rated load (reduced to +80°C.); altitudes to 50,000 ft. *The Superior Electric Co.*, Dept. PH, 83 Laurel St., Bristol, Conn.

Subminiature Tubes for Guided-Missile Application. Feature a shortened mount structure designed to meet severe mechanical and environmental demands. *Sylvania Electric Products Inc.*, 1740 Broadway, New York 19, N.Y.

Gaseous Diffused-Junction Transistor. Makes possible the first high power transistorized servo and audio output systems for use in high temperatures. *Texas Instruments Incorporated*, 6000 Lemmon Ave., Dallas 9, Tex.

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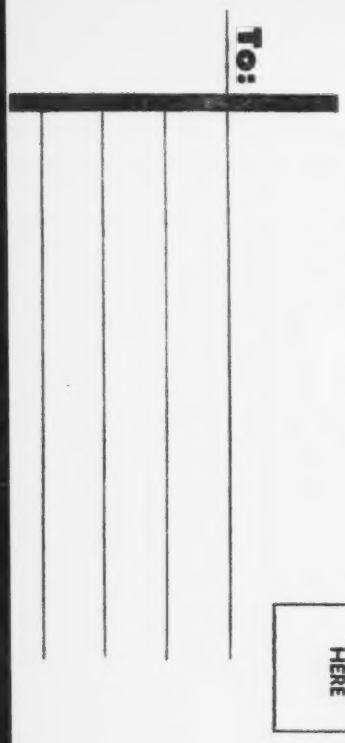

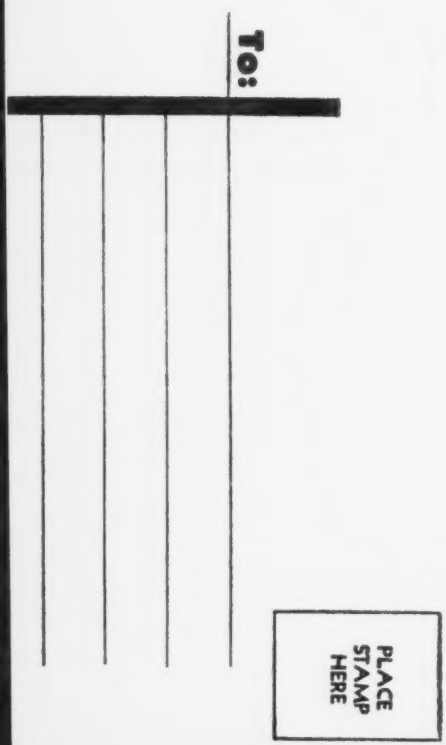

Push-Button Switches for Temperature Measuring Circuits. These units permit frequent checking of many remote thermocouples or resistance bulbs from one location. *Thermo Electric Co., Inc.*, Saddle Brook, N.J.

High-Frequency Silicon Transistors. Eleven types provide a range of current gains up to 60 and collector voltage ratings to 45 volts; feature low collector cut-off currents. *Transitron Electronic Corp.*, Melrose 76, Mass.

Silicon Diodes for Computer Service. Particularly useful in military computers where high temperatures are encountered. *Transitron Electronic Corp.*, Melrose 76, Mass.

Cap Nuts Fabricated From Black Nylon. Useful in electrical installations where high dielectric strength and resistance to corrosion are important. *Weckesser Co.*, Dept. ARN, 5701 Northwest Hwy., Chicago 30, Ill.

DRAFTING ROOM, PRODUCTION, & MISC. EQUIPMENT

Magnetic Air-Hose Nozzle Holder. Clamps to machine tools at point of use; consists of a pliable rubber nozzle fastened to Alnico magnets of 110-lb. or 35-lb. pulling power. *The Dilley Mfg. Co.*, 1655 Doan Ave., Cleveland 12, Ohio.

Drafting Templates for MS Flareless Fluid Fittings. Five templates contain cutouts for 3/16 and 5/16 in. tube sizes, 1/4 and 3/8-in., 1/2 and 3/4-in. *E. F. Twomey Co., Inc.*, P.O. Box 15913, Los Angeles 15, Calif.

RESEARCH & TEST EQUIPMENT

"CompuDyne" Dynamic Control Systems. 24-page Bulletin G-102 describes complete systems for applications in wind tunnels, engine and engine component test facilities, structural dynamic loading, etc. *CDC Control Services, Inc.*, 403 S. Warminster Rd., Hatboro, Pa.

Model 250 Functional Tester. Tests complex relay systems and associated wiring; features plugboard programing. *DIT MCO, Inc.*, Electronics Div., 911 Broadway, Kansas City, Mo.

Strain-Gage Force Pickups. Measures forces in applications where the deflection caused by the force is limited to 0.00035 in. *Dynamic Instrument Co., Inc.*, 28 Carleton St., Cambridge, Mass.

Servo-Operated "Press-I-Cell." 12-page catalog describes an instrument for the precise measurement of absolute gage or differential fluid pressures. *Fischer & Porter Co.*, 99 Jacksonville Rd., Hatboro, Pa.

Turbine Flowmeter. 8-page catalog 10C150 describes device for the precise measurement of liquid flow. *Fischer & Porter Co.*, 75 Jacksonville Rd., Hatboro, Pa.

Axial Accelerometers. Feature extremely low cross-talk (0.01 g/g max.) and low threshold; sense linear acceleration by means of a spring-supported, linear ball-bushing mounted mass which moves along a case hardened shaft. *G. M. Giannini & Co., Inc.*, 918 E. Green St., Pasadena 1, Calif.

Remote Controlled Missile Hydraulic Power Check-Out Unit. Serves as a source of high-pressure hydraulic power for missiles that require precise circuit check-out prior to launching. *Haskel Engineering & Supply Co.*, Glendale, Calif.

"Digimaf" Digital Mass Flowmeter. For measuring true mass flow rate of liquids, vapors, gases, or multiphase combinations over temperatures ranging from −423° to +1,000°F. *Inertial Instruments Inc.*, 1738 Colorado Ave., Santa Monica, Calif.

Model 2249 Gyro Drift Recorder. Claimed capable of detecting, indicating, and recording with extreme accuracy the minute increments of drift characteristic of modern high-precision gyros. *Lear, Inc.*, Learcal Div., 3171 S. Bundy, Santa Monica, Calif.

Character Printer for the AUTOGRAF X-Y Recorder. Permits automatic identification of up to six different point plotted curves. *F. L. Moseley Co.*, 409 N. Fair Oaks Ave., Pasadena, Calif.

Portable Hardness Tester. Can be used in any position to test the hardness of any size, shape, or type of metal. *Newage Industries, Inc.*, 222 York Rd., Jenkintown, Pa.

Optical Tracking Instruments & Systems. 16-page brochure describes company's devices for recording and tracking missiles and air-borne objects. *Perkin-Elmer Corp.*, Norwalk, Conn.

10-Bit Transistorized Digital Coder. Constructed entirely on printed wiring boards; extremely compact; resistant to high shock and vibration. *Radiation, Inc.*, P.O. Box 37, Melbourne, Fla.

"Programmer Counter" Provides Automatic Control of Test Limits. Used to turn on and off test apparatus whose limits are sensed by strain gages, thermocouples, or other transducers that have a maximum output not exceeding 100 mv. d.c.; eliminates the need for manual control of test cycling. *Spar Engineering & Development, Inc.*, Wyncote, Pa.

"Servo-Ratio Multimeter" Computer Test-Instrument. Computes voltage ratios by dividing the voltage to be measured by the reference voltage obtained from the computer. *Union Switch & Signal*, Div. of Westinghouse Air Brake Co., Swissvale, Pa.

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Long arm of SAC's deterrent force, Boeing Airplane Company's intercontinental B-52 has as its nerve center the AN/ASB-4 Bombing/Navigation System, developed and produced by International Business Machines for the United States Air Force.

Aside from pinpoint navigational and bombing accuracy, this complex system is notable for a high level of reliability achieved by painstaking care in detail design, rigorous proofing of each part, and a system configuration comprising unit-tested modules.

Servomechanisms, Inc., in addition to quantity production of the Pressure Transducers and Quadrature Rejector units which are important input and control elements of this system, has also contributed to the development of several other important elements of this system.

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Now the air traveller on a regional route and the executive in a business aircraft can enjoy air-conditioned comfort unsurpassed by any transportation medium. In flight or on the ground, he will be kept comfortably cool if he's in a Fairchild F-27. The F-27 has air conditioning—and pressurization—equalled only by the most luxurious transcontinental and intercontinental airliners.

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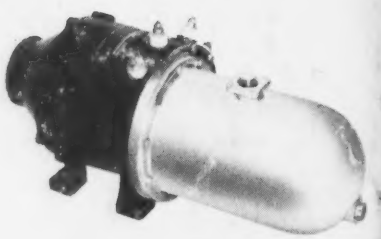
The Heli-Rotor Compressor for the F-27's Freon refrigerator system.



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